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THE PROGRESS IN TESTING FULL-SIZE PIECES UNDER PRACTICAL CONDITIONS, TOGETHER WITH LOCOMOTIVE TESTING IN THE UNITED STATES.[1]

BY

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IN the "Proceedings of the American Society for Testing Materials," for 1904, appeared an article by the author, entitled "A Brief Review of the Status of Testing in the United States." In that article two periods were considered, the second of which began shortly after 1875, or about the time when the Emery testing machine of 800,000 pounds capacity was constructed for, and installed at, the Watertown Arsenal. This second period was marked by the constantly-increasing recognition of the fact that the engineer needs the results of testing full-size pieces under practical conditions, in order to know what constants to use when making designs of structures and machines, and in order to verify or to disprove the theoretical considerations upon

[1] Presented at the meeting of the Mechanical and Engineering Section held Thursday, October 10, 1912, based on a paper of the same title presented by the author at the Sixth Congress of the International Association for Testing Materials.

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which his calculations are based, or how to modify them. The tests of this second period were, in that paper, classified as:

1. Tests for the purpose of securing good material and reasonable specifications.

2. Tests of full-size pieces, under practical conditions.

3. Investigations made for the purpose of ascertaining the laws of variation of the different properties of a substance.

With the first of these classes, though it is all-important and although the American Society for Testing Materials has devoted to it the greater part of its energies and has already accomplished most valuable and important results, the present paper will not deal—its object being to outline the progress made in and the present status of the second class.

In order to explain the importance of testing full-size pieces, a few illustrations will be given, as follows:

(*a*) In full-size eyebars, the tensile strength is always less per square inch than that of a small sample of the same steel.

(*b*) In steel columns, whether built up as in bridges or solid as in connecting rods of locomotives, no tests of small samples will show the strength.

(*c*) In timber beams or columns, there are always knots, cracks, crooked grain, or other defects, in the full-size member which are not allowed to be in the small sample, and they exert the greatest influence on the strength on the full-size piece.

(*d*) In cases where there are complicated stresses, full-size tests are needed to determine the strength of the specimens.

In the early days the limitations to the capacities of the testing machines in use precluded the possibility of the second class of investigations, and hence it is that the development of such tests must necessarily go hand in hand with the growth in capacity of the machines—the recognition of the need for their results leading to the construction of more powerful ones, and their possession rendering possible the making of the experiments.

While transverse tests of some full-size pieces can be performed by means of machines of a capacity of 100,000 pounds, and sometimes of less, tensile and compression tests of full-size pieces are practically impossible with machines of less than 300,000 pounds, and many without those of far greater capacity.

Almost all the powerful testing machines in the United States, except that at Phœnixville and that at Ambridge, Pa., are either

"Emery," "Olsen," or "Riehle" machines. The writer, therefore, secured from the makers lists of all the machines of their manufacture in use in the United States, of 300,000 pounds capacity and upwards, to determine which establishments have the necessary equipment for making such tests. By communicating with them and with others the author has endeavored to ascertain what full-size testing has been, and is being, performed in this country and the nature of the results obtained.

In the light of this information, which, though not assumed to be complete, is quite comprehensive, he will endeavor to present here the general situation at the present time.

A study of the information thus obtained makes it evident that the testing of full-size pieces, in the United States, has developed enormously since the year 1875, and that powerful testing machines are now in the possession of the laboratories of many industrial concerns, such as steel works, bridge-building works, railroads, testing laboratories; also of engineering schools, including experiment stations and of others.

The work done with the aid of these machines may be classified as follows, viz.:

(1) Investigations made for the general good, most of which have been published and are available to all engineers.

(2) Work performed primarily for the benefit of the concerns making the experiments, but which is of such a nature that they have no object in keeping it secret. Most of this has also been published, and is likewise available.

(3) Work done for the purpose of solving some of the problems that arise in connection with the business of the firm, the results of which they do not wish to impart to their competitors.

In the first class are included the results obtained by the Government laboratories and by the engineering schools. The existence of the second and of the third class makes it evident that many large concerns find it not only to their advantage, but also necessary, to be equipped with powerful testing machines in order to solve problems affecting their business.

In attempting a brief review of the situation up to and at the present time, we find that a large amount of work of this character has been carried on by the following Government laboratories:

(1) The Bureau of Standards of the Department of Commerce and Labor.

(2) The Watertown Arsenal of the Ordnance Department, *i.e.*, of the War Department.

(3) The Agricultural Department.

(4) The Geological Survey of the Interior Department.

If we consider this work chronologically, we have:

(1) That at the Watertown Arsenal.

The installation of the well-known Emery testing machine of 800,000 pounds capacity, soon after 1875, gave it a long lead in the matter of full-size testing, and it continued to perform such work throughout a period when the facilities elsewhere were few, and when the need was not as fully recognized as to-day. It is not surprising even now to find that the sum total of such work done by that machine is very large and that the results have excited a great deal of influence upon engineering practice. Among the lines of investigation carried on, of which the results may be found in the reports of the Ordnance Department, entitled "Tests of Metals" covering a period from 1880 to 1905, may be mentioned:

(1) Tensile strength of large eyebars.

(2) Tensile strength of large wire and other ropes.

(3) Tensile strength of riveted joints with six or more rivets.

(4) Tensile strength of riveted and pin connections.

(5) Compressive strength of wrought-iron and steel columns.

(6) Compressive strength of cast-iron columns.

(7) Compressive strength of plain and built-up timber columns.

(8) Compressive strength of columns of reënforced concrete of a great many kinds.

(9) Compressive strength of masonry piers.

(10) Compressive strength of large specimens of stone.

(11) Investigations of the causes of defective rails.

(12) Investigations of the effects of repeated stress upon metals.

(13) Many tests upon the strength and other properties of metals for ordnance purposes.

The above is only a brief and partial list.

Besides the tests made for the general good, many were made for private firms, the results of which, as a rule, have

not been published. Each of the classes enumerated might be divided into many sub-classes; thus No. 8 includes a very long and detailed investigation of the effects of different kinds of reënforcement; and this and No. 9 furnish the means of comparing strength and other resisting properties of reënforced concrete with those of masonry.

Many properties of concrete were also studied, among them being the effects of high temperatures.

Under No. 11 investigations were made of the steel from different parts of the ingot, and of the defects in the ingot itself. Tests were also made upon the effects of high temperatures upon steel and upon riveted joints.

(2) Next in order chronologically comes the work done by the Bureau of Forestry, of the Department of Agriculture, upon the strength of full-size pieces of timber. This series of tests was begun about 1903. (A former series of timber tests by the same bureau was mostly concerned with the tests of small pieces.)

The kinds of timbers tested have been mainly the following:

(*a*) Loblolly pine.
(*b*) Long-leaf pine.
(*c*) Short-leaf pine.
(*d*) Douglas fir.
(*e*) Western larch.
(*f*) Tamarack.
(*g*) Western hemlock.
(*h*) Redwood.

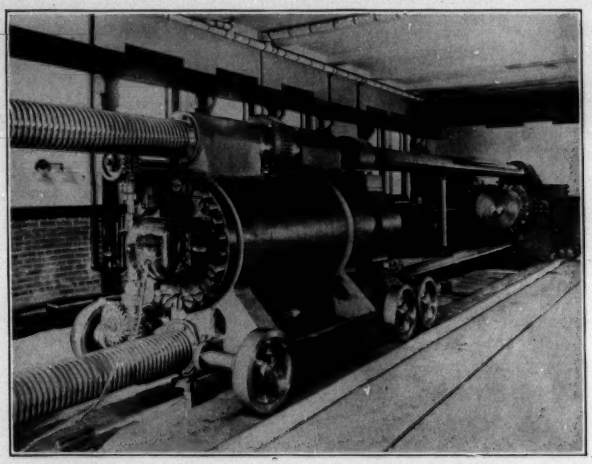
(3) The other Government department which is doing work of this character is the Bureau of Standards of the Department of Commerce and Labor, and this, moreover, is the bureau to which we must look principally in the future for results of this class of investigations.

While it is only during the last three or four years that it has undertaken the testing of the strength of materials on an extensive scale, one Emery testing machine for it is already built and another is nearing completion. The latter has a capacity of 2,300,000 pounds in compression and 1,115,000 pounds in tension. This machine is shown in Fig. 1. Besides these, the Bureau already has a number of other machines. Moreover, the laboratories formerly under the direction of the Geological Survey,

which devoted the greater part of their energies to tests of concrete and reënforced concrete, have been transferred to the Bureau of Standards, thus adding to their equipment a considerable number of Olsen and Riehle machines, the largest one being an Olsen machine of 10,000,000 pounds capacity.

The Bureau has, for some time, been engaged in making strain measurements upon structures in various parts of the United States. These measurements have been made upon: (*a*) Bridges,

FIG. 1.



Emery testing machine at the Government Bureau of Standards.

(*b*) buildings, (*c*) street pavements, and (*d*) boilers, and embrace also the lock gates of the Panama Canal.

The Bureau is arranging for tests upon full-size built-up columns of steel.

Tests are also being made in regard to steel rails.

(4) As to the work done by the Geological Survey, the results have been published by the Bureau of Standards.

The chief laboratory was erected and operated at the grounds of the St. Louis Exposition of 1904. It was mostly concerned with concrete and reënforced concrete, and, while the tests were under the direction of the Geological Survey, they were done with

the collaboration of the Joint Committee on Reënforced Concrete. This work dealt especially with reënforced concrete beams, but included a great deal upon concrete and also upon cement and mortar.

Passing next to the steel and bridge works, we find that the two machines of the greatest capacity owned by any of them are:

(*a*) The testing machine of the Phœnix Bridge Company, of 2,400,000 pounds capacity, for either tension or compression, located at Phœnixville, Pa. This machine is shown in Fig. 2.

(*b*) The testing machine of the American Bridge Company, of 4,000,000 pounds capacity, for tension only, located at Ambridge, Pa.

The Phœnixville machine was built in 1864, and was at first employed mostly in the testing of full-size eyebars for the principal railroads, manufacturers and consulting engineers; also of eyebars built up of plates for the larger New York bridges. This machine has tested eyebars of nickel steel having a cross section of 18 inches by 2 inches.

Later, many tests upon full-size compression members were made for various railroads and others, a number of them involving a special study of the action of the pin plates, rivets, and other details.

Recently, more than 50 tests of compression members, both of nickel and of carbon steel, have been performed, including studies of the movement of the material, action of rivets, pin bearings, and other details. A great many tests have been made of tension joints and of tension members for bridges; also about twenty tests of small-size models of large compression members for the Quebec Bridge.

The Ambridge testing machine was built in 1904, from designs of Mr. James Christie. Its capacity is 4,000,000 pounds, while the greatest load that it has sustained was 3,500,000 pounds in testing vanadium steel yokes for the lock gates of the Panama Canal.

This 4,000,000-pound machine had tested, up to May 17, 1912, 1,750 eyebars, all except 166 having been manufactured at Ambridge, the latter tests having been made for the Virginia Bridge Company. Also, 250 tests were made on beams, castings, couplers, etc.

The Ambridge plant has forged and tested eyebars for the following manufacturers:

The McClintic-Marshall Construction Company.
Pennsylvania Steel Company.
Baltimore Bridge Company.
Canadian Bridge Company.
Virginia Bridge Company.
Penn Bridge Company.
Mt. Vernon Bridge Company.
Bellefontaine Bridge Company.
Central States Bridge Company.
Joliet Bridge and Iron Company.
Midland Bridge Company.
Northwest Steel Company.
Louisville Bridge Company.
Bucyrus Company.
American Locomotive Company.
Guerber Engineering Company.
Vanadium Steel Company (experimental tests).

It has also forged and tested eyebars for almost every large railroad in the United States, and for railroads in Japan, Korea, China, South America, Mexico, and Canada.

The following steel works are equipped with testing machines of 600,000 pounds capacity, of either the Olsen or Riehle type:

1. American Steel and Wire Company
2. Pressed Steel Car Company

The following with one of 500,000 pounds capacity, viz.:

3. Scullin, Gallagher Iron and Steel Company

The following with machines of 400,000 pounds capacity:

4. American Steel Foundries Company
5. Bethlehem Steel Company
6. Carnegie Steel Company, Pittsburgh, Pa.
   Carnegie Steel Company, Charlton, Pa.
   Carnegie Steel Company, Munhall, Pa.
7. Midvale Steel Company
8. Johnson Company
9. Jones & Laughlin
10. Inland Steel Company
11. Lorain Steel Company
12. McConway & Torley Company
13. Republic Iron and Steel Company
14. Worth Brothers

Many steel companies are equipped with testing machines of 300,000 pounds capacity. Before referring to the work that has been performed, I will say that the existence of so many large machines among the steel and bridge works renders evident the fact that machines of large capacity are needed by these firms.

The list given above is compiled from the data provided by the makers of testing machines.

Having received this information from them, I proceeded to write to these and other works, asking what they had done and were doing by way of testing full-size pieces, and while many replied that they made no tests of this kind, except to use the machines in their business, others gave me information which I will attempt to summarize here:

(1) Tests of wire rope.
(2) Tests of full-size bars.
(3) Tests of full-size shapes.
(4) Tests of boiler tubes.
(5) Drop and deflection tests of rails and of axles.
(6) Drop tests of tires.
(7) M. C. B. coupler tests.
(8) Tests of rail joints.

The results of many of the eyebar tests made at Ambridge and Phœnixville, and many of the full-size column tests made at Phœnixville, have been published.

As to the railroads, the following is a summary of the tests cited in the replies which I received:

(1) Atchison, Topeka & Sante Fe Railroad, full-size eyebars made at Ambridge.

(2) Baltimore & Ohio Railroad, which owns a 600,000-pound Olsen machine:

(*a*) Full-size eyebars in the course of inspection.
(*b*) Extensometer tests on bridge members.

An account of the latter is given in a paper by J. E. Greiner in the *Proceedings of the American Society of Civil Engineers.*

(3) Chicago, Burlington & Quincy Railroad, spliced sills, mostly drop tests, the account of which is given in a report of a committee of the Master Car Builders' Association.

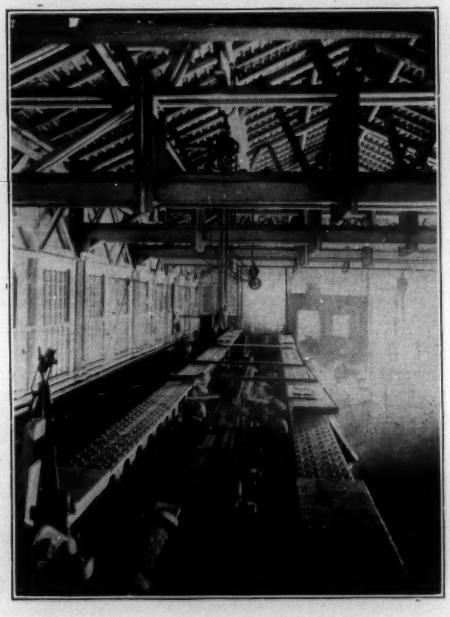
(4) The Chicago, Milwaukee & St. Paul Railroad.

(*a*) Timber stringers by Onward Bates, 1890.

(*b*) Reënforced concrete beams by J. J. Hardy in 1904–1905.

(*c*) Iron pulley blocks at the University of Wisconsin in 1908.

FIG. 2.



Testing machine at the Phœnix Bridge Company.

The tests of Onward Bates were published in the *Proceedings of the American Society of Civil Engineers* and the others in those of the *Western Society of Engineers.*

(5) The New York Central Railroad:

(*a*) Full-size eyebars.

(*b*) Full-size cover plate cut from a plate girder in service.

(*c*) Bending tests of rails.

(*d*) Air-brake beams, journal boxes, and draft gear.
(*e*) Axles, couplers, and car wheels by drop tests.
(*f*) Side frames.

(6) The Pennsylvania Railroad:
(*a*) Full-size eyebars, reported in *Engineering News*.
(*b*) Full-size compression members, by C. P. Buchanan.
(*c*) Full-size compression members, by J. E. Howard and C. P. Buchanan, published in the *Proceedings of the American Society of Civil Engineers*.
(*d*) Chains and couplers.

The following firms, which were neither steel works nor railroads, replied as follows:

(1) General Electric Company:
(*a*) Fastening pole pieces to spider in revolving field.
(*b*) Securing turbine bucket-blades in wheel veins.

(2) Robert W. Hunt Company:
(*a*) Eyebars.
(*b*) Brick and reënforced columns.
(*c*) Reënforced concrete floor studs and panels.

(3) The Pittsburgh Testing Laboratory, which owns a 600,000-pound Olsen machine:
(*a*) Full-size eyebars.
(*b*) Inspecting full-size members for the Quebec Bridge.

(4) The Baldwin Locomotive Works, which owns a 600,000-pound Olsen machine:
(*a*) Equalizer beam.
(*b*) Full-size bars.

ENGINEERING SCHOOLS AND EXPERIMENT STATIONS.

The following summaries of classes of full-size tests made by various engineering schools have been compiled from the replies received to my letters of inquiry. Even though they may not be complete, they will serve to show the interest taken in, and the part played by, these schools in the making of investigations of this character.

(1) University of Illinois:

Their most powerful testing machine is one of 600,000 pounds capacity. The following is a summary of the kinds of full-size tests mentioned in their reply to my letter of inquiry:

(*a*) Concrete; reënforced concrete beams; reënforced concrete columns.
(*b*) Culvert pipes of reënforced concrete and of cast iron.
(*c*) High-speed tool steels.
(*d*) Resistance of tubes to collapse.
(*e*) Roof trusses.
(*f*) Chain links.
(*g*) Base and bearing plates for columns and beams.
(*h*) Timber beams.
(*k*) Built-up columns.
(*l*) Riveted joints of nickel steel.
(*m*) Holding power of railroad spikes.
(*n*) Brick columns and terra-cotta block columns.

(2) Lehigh University:

Their most powerful testing machine is one of 800,000 pounds capacity. In their reply to my letter of inquiry they cite tests of plain and of reënforced concrete columns.

(3) Massachusetts Institute of Technology:

Their most powerful general testing machine is one of 300,000 pounds capacity, although they have, also, an arch testing machine of 400,000 pounds capacity.

The following is the summary of many of their full-size tests:

(*a*) Tensile tests of
1. Bolted and riveted joints.
2. Wire rope.
3. Cotton, Manila and hemp rope.
4. Efficiency of knots and hitches.
5. Concrete.

(*b*) Compressive tests.
1. Bricks and brick piers.
2. Wrought-iron pipe columns.
3. Timber columns, with and without bolsters.
4. Timber across the grain.
5. Concrete and reënforced concrete columns (including some at high temperatures).
6. Cast-iron water pipes.

(*c*) Transverse tests.
1. Wrought-iron and steel "I" beams.
2. Masonry arches.
3. Timber beams.

4. Headers and other framing joints.
5. Splice plates of girders.
6. Granite.
7. Pulley arms and rims.

(*d*) Torsional tests.

1. Wrought-iron shafting.
2. Steel shafting, including cold rolled.
3. Flange couplings.

(4) University of Pennsylvania:

Their most powerful testing machine is one of 600,000 pounds capacity. The following is a summary of the kinds of full-size tests mentioned in their reply to my letter of inquiry.

(*a*) Reënforced concrete beams.
(*b*) Standard "I" beams, Bethlehem "I" beams and girder beams.
(*c*) Concrete piers and columns.
(*d*) Concrete cylinders.
(*e*) Steel columns
(*f*) Concrete arches.

(5) Purdue University:

Their most powerful testing machine is one of 300,000 pounds capacity.

The following is a summary of the kinds of full-size tests mentioned in their reply to my letter of inquiry:

(*a*) Brake beams and car bolsters.
(*b*) Manufactured pieces.
(*c*) Timber beams.

(6) Rensselaer Polytechnic Institute:

Their most powerful testing machine is one of 1,200,000 pounds capacity.

The following is a summary of the kinds of full-size tests mentioned in their reply to my letter of inquiry:

(*a*) Built-up library stacks.
(*b*) Lap joints for gasometers.
(*c*) Cast-steel rail joints.
(*d*) Calibration of dynamometers for dynamometer car.
(*e*) Car couplers.
(*f*) Concrete-filled pipe columns.
(*g*) Fire tests of concrete mixtures.
(*h*) Reënforced concrete beams.

(7) West Virginia University:

Their most powerful testing machine is one of 600,000 pounds capacity.

The full-size tests mentioned in the reply to my letter of inquiry are:

(*a*) Brick and wooden beams.

(8) University of Wisconsin:

Their most powerful machine is one of 600,000 pounds capacity. The following is a summary of the kinds of full-size tests mentioned in their reply to my letter of inquiry:

(*a*) Tests on plain and reënforced concrete, including beams and columns.

(*b*) Tests of reënforced concrete beams.

(*c*) Tests of plain and reënforced concrete columns.

(*d*) Tests of reënforced concrete columns, subjected to repeated and eccentric loads.

(*e*) Tests on bond between concrete and steel in reënforced concrete beams.

The preceding summaries of work of this character done in the United States, though not complete, make evident the enormous progress that has been attained in recent years in the testing of full-size pieces under practical conditions.

LOCOMOTIVE TESTS.

This paper has, thus far, been devoted exclusively to the progress made in the United States in the testing of full-size pieces under the conditions of practice, where the object has been to determine the strength and other resisting properties of the material. In the case of machinery, however, and especially of prime movers and other motors, many other kinds of full-size tests are required, and the making of them is due to the recognition of the same principle that prevails in those already mentioned, viz., that the results obtained by experimenting upon small models, while they may be suggestive and may furnish valuable information, do not take into account all the conditions that exist in the full-size machine or motor, and that it is unsafe to predict its behavior in practice, from the results obtained by such experiments, when a portion of the conditions have been left out of consideration. Any attempt to enumerate the cases

where such investigations are needed would be too extensive for any one paper, but a few may be mentioned by way of illustration:

(1) Road tests of locomotives with or without the aid of a dynamometer car.

(2) Stationary tests of locomotives.

(3) Tests of marine motors, whether they employ steam or gasoline as the working fluid, whether they are reciprocating engines or steam turbines, and whether they include or not speed tests and towing tests.

(4) Tests of stationary prime movers, whether they are reciprocating engines or turbines, and whether steam, gas, gasoline, or water be the working fluid.

(5) Power plant tests, including the friction losses throughout the mill or manufactory.

(6) Tests of electric motors.

(7) Tests for balancing high-speed rotative machinery, as dynamos, centrifugal machines, etc.

While there has been a steady increase in the number of tests of this character, nevertheless the principle mentioned above has been recognized for a much longer time than in the case of investigations involving the strength of materials.

In considering the experiments with which we are now dealing, however, the most important development has been the progress made in the attainment of greater scientific accuracy. Thus at the present time plant tests of such short duration as to vitiate the correct determination of the coal consumed are less and less in number and are given less and less credence. Of these various classes the only ones that will be considered here are:

(1) Stationary tests of locomotives.

(2) Road tests of locomotives.

The first are the most recent and the most easily summarized. They are carried on under conditions that can be fully controlled, and furnish a very large amount of most important and valuable information, though, of course, lacking the necessarily variable conditions that exist in road tests.

The development of stationary plants for making locomotive tests, up to the year 1904, has been described in a paper published by Prof. W. F. M. Goss, in the *Proceedings of the*

American Society of Mechanical Engineers for that year. Only a brief summary of what was accomplished up to that time will be given here.

In the paper referred to, Goss mentions:

(1) The early, though rather crude, attempt made in Russia in 1881 and 1882 by Mr. Alexander Borodin.

(2) The first testing plant at Purdue University in 1890.

(3) The plant at Columbia University in 1893.

(4) The temporary plant established at Kakauna by Mr. Robert Quayle in 1893.

(5) The second plant at Purdue University in 1894.

(6) The plant of the Chicago & Northwestern Railroad at Chicago in 1895.

Besides the above he gave a description of the plant of the Pennsylvania Railroad Lines, then being established at the St. Louis Fair.

In the discussion Mr. E. Worthington stated that Mr. Churchward, of England, was imitating the example.

Professor Goss stated that Mr. M. V. Goloboloff, of Russia, was building a plant at the Putiloff Works, at St. Petersburg, Russia.

The work done by these plants up to that time, as explained in the papers referred to, may be summarized as follows:

(1) The work of Mr. Borodin dealt especially with the effects of steam jacketing.

(2) The results obtained by Goss, prior to the fire which destroyed the first plant at Purdue University, were published in two papers presented by him to the *American Society of Mechanical Engineers*, one in 1894 and the other in 1896.

They included: (*a*) efficiency tests; (*b*) studies of counterbalancing; (*c*) studies of the effects of long indicator pipes; (*d*) a study of the differences in the results obtained by running with the throttle wide open or partially closed.

(3) The work done by means of the temporary plant at Kakauna was devoted especially to a study of the action of the front end.

(4) That of the second plant at Purdue University up to 1904, when three locomotives had been made the subjects of experiment, included many investigations, among which were the following:

(*a*) A study of the amount of steam per horse-power per hour required by the locomotive under favorable conditions.

(*b*) Definition of the evaporative performance of the locomotive boiler.

(*c*) Degree of dryness of the steam in the locomotive boiler.

(*d*) Comparison of the results when the locomotive output is controlled by the reverse lever with those when the control is partly by the throttle.

(*e*) Point of most economical cut-off for a simple locomotive.

(*f*) The value of the steam pipes in the smoke-box as a superheater.

(*g*) Action of the steam jet in the production of draft.

(*h*) Study of the losses involved in the emission of sparks.

(*i*) Study of the proportions of exhaust pipes and stacks.

(5) The chief work performed by the plant of the Chicago & Northwestern Railroad at Chicago, up to 1904, was that carried on under the direction of a committee of the *Railway Master Mechanics' Association*, covering exhaust pipes and steam passages, the account of which is published in the proceedings of that society for 1896.

Other work performed by means of this plant was:

(1) Studies of the values of different kinds of coal.

(2) Study of the efficiency of different types at different speeds and cut-offs.

(3) Effects of changes of lead and inside clearance and of defects in design of valve gear.

THE LOCOMOTIVE TESTING PLANT OF THE PENNSYLVANIA RAILROAD.

This plant, which is the finest in the country, was designed by Mr. A. S. Vogt, then mechanical engineer of the railroad; the plans were begun in 1903, and the first locomotive was placed upon it on May 25, 1904.

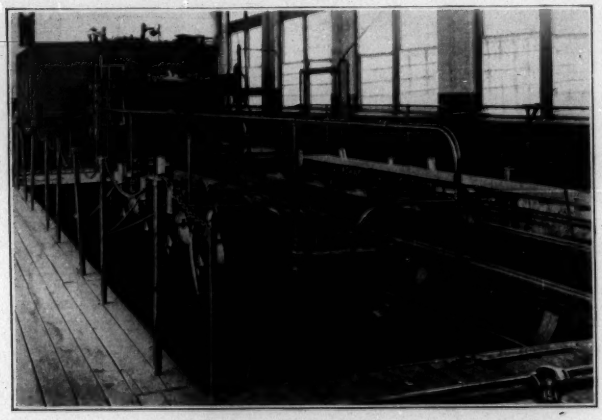
It was first located at the grounds of the St. Louis Exposition, during the time of the World's Fair held in that city in 1904;

and was afterwards transferred to its permanent position at Altoona, Pa.

Fig. 3 is a general view of this plant, with no locomotive on it. Fig. 4 shows the housing of the dynamometer. In Fig. 5 is shown a locomotive in position.

A very complete and fully-illustrated description and account of what was accomplished with it while at St. Louis has been published in book form by the Pennsylvania Railroad.

FIG. 3.



Locomotive testing plant, Pennsylvania Railroad. General view.

These tests were very complete, and included, as nearly as possible, the entire range of conditions of service. Eight locomotives were tested, of which four were freight and four passenger engines.

Of the freight locomotives three were simple engines, of the consolidation (2–8–0) type, with their total weights and their weights on drivers approximately equal.

These three were:

(*a*) A simple consolidation (2–8–0), owned by the Pennsylvania Railroad, and numbered 1499:

Total weight	194,200 pounds
Weight on drivers	173,000 pounds

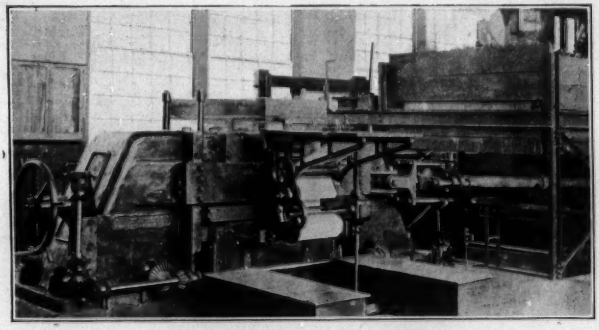
(*b*) A simple consolidation (2–8–0) owned by the Lake Shore & Michigan Southern Railroad, built at the Brooks Locomotive Works, and numbered 734:

Total weight	181,300 pounds
Weight on drivers	162,600 pounds

(*c*) A two-cylinder cross-compound consolidation (2–8–0) owned by the Michigan Central Railroad, built at Schenectady by the American Locomotive Company, and numbered 585:

Total weight	189,000 pounds
Weight on drivers	164,500 pounds

FIG. 4.



Locomotive testing plant, Pennsylvania Railroad. Dynamometer housing.

The fourth freight locomotive was:

(*d*) A four-cylinder tandem compound Sante Fe (2–10–2) owned by the Atchison, Topeka & Sante Fe Railroad, built at the Baldwin Locomotive Works, and numbered 929:

Total weight	285,740 pounds
Weight on drivers	233,760 pounds

The four-passenger locomotives were all four-cylinder, balanced compound locomotives of the Atlantic (4–4–2) type. Two were built in the United States, one in Germany and one in France.

(*e*) A Vauclain four-cylinder, balanced compound Atlantic type (4–4–2), owned by the Atchison, Topeka & Santa Fe Railroad, built by the Baldwin Locomotive Works, and numbered 535:

Total weight	201,500 pounds
Weight on drivers	99,200 pounds

(*f*) A Cole four-cylinder, balanced compound Atlantic type (4–4–2), owned by the New York Central Railroad, built at Schenectady by the American Locomotive Company, and numbered 3000:

Total weight	200,000 pounds
Weight on drivers	110,000 pounds

(*g*) A four-cylinder, balanced compound Atlantic type (4–4–2), provided with a Pielock superheater, built by the Hanoverische Maschinen Gesellschaft of Hanover, Germany, presented by them for test, and numbered 628:

Total weight	133,350 pounds
Weight on drivers	65,350 pounds

(*h*) A De Glehn four-cylinder, balanced compound Atlantic type (4–4–2), owned by the Pennsylvania Railroad, built by the Société Alsacienne de Constructions at Belfort, France, and numbered 2512:

Total weight	164,000 pounds
Weight on drivers	87,850 pounds

The chief purpose of the tests, as stated in the programme, was "to establish with accuracy the actual performance of certain typical locomotives."

In carrying this out, a careful study was made both of the boiler and of the engine performance, including:

(1) A study of the efficiency of the boiler under the various conditions of running.

(2) A study of the capacity of the boiler.

(3) The relative advantages of small and of large grates.

(4) A study of the furnace losses.

(5) A study of the temperatures in the fire-box and in the smoke-box.

(6) A study of the draft in the ash-pan, in the fire-box, and in the smoke-box.

(7) A study of the relation between the CO formed and the temperature in the fire-box.

(8) A study of the advantages of throttling as compared with running with the throttle wide open and regulating by the cut-off.

(9) A study of the effects of the brick arch.

(10) A study of the losses due to imperfect combustion and those due to excess of air, and many other features concerning the boiler.

(11) A study of the horse-power developed by freight engines and that by passenger engines.

(12) A study of the maximum tractive effort at different speeds.

(13) A study of the steam consumption per horse-power per hour at different speeds and cut-offs.

(14) A study of the relative economy of compound as compared with simple locomotives when developing different horse-powers.

(15) A study of the per cent. of cylinder power realized at the drawbar.

(16) A study of the effect of using greases for lubrication as compared with the use of oil.

(17) A study of the various vibrations, as jerking, pounding, nosing, and other features.

After the plant was moved to Altoona another locomotive was tested in the same manner as those at St. Louis, viz.:

A simple locomotive of the Atlantic type (4–4–2), owned by the Pennsylvania Railroad, and numbered 5266:

Total weight	184,167 pounds
Weight on drivers	110,001 pounds

Besides the above, the following, among other investigations, have been made by means of this plant:

(1) A series of tests of briquettes made by the United States Geological Survey from a low volatile or semi-bituminous coal.

(2) Tests of a fire-door with enlarged air-admission openings and a deflector.

(3) Tests of various coals.

(4) Tests of a hollow fire-brick arch.
(5) Tests of the result of varying grate area.
(6) Tests of a fire-kindler.
(7) Tests of a self-cleaning front end.
(8) Tests of an E–2–d locomotive.
(9) Tests of the regular level method of firing as compared with the bank method.
(10) Tests of a Baldwin superheater.
(11) Tests of the effects of cylinder drainage.
(12) Tests of the throttling as compared with regulating by reverse lever.
(13) Tests of the Parsons combustion system.
(14) Tests of a coal with little volatile matter.
(15) Tests of the Jones stoker.
(16) Tests of a special grate.
(17) Tests to determine the increase, if any, of the coal burned due to blowing the air-pump exhaust through the stack.
(18) Tests of lubricators.
(19) Tests of a K–2 Class locomotive, No. 7510.
(20) Tests of Baker Pilliod valve gear.

ROAD TESTS.

Road tests of locomotives were made on many railroads long before stationary plants were ever thought of. The principal development along these lines has been the tendency to take more care, in order to avoid obtaining apparent results that are misleading.

Many difficulties have to be overcome that do not arise in stationary tests, as already explained. On the other hand, it is precisely the performance of the locomotive under the variable conditions that arise in practice that the railroad man needs most to know.

Only a few of the precautions that ought to be carefully observed will be mentioned here:

(*a*) The coal or other fuel consumed.
(*b*) The water evaporated.
(*c*) The power developed, both in the cylinders and at the drawbar.

It would therefore seem that, as a matter of course, the person responsible for the test would endeavor to secure accuracy

in the determination of these items, and yet many have been made where the necessary precautions have not been taken, and where, consequently, the conclusions have been erroneous.

Commenting upon these items we may observe:

(*a*) In order that reasonable accuracy may be obtained in the determination of the coal consumed, while it is necessary that it be correctly weighed, it is also of great importance that the duration of the test should be of a sufficient length to insure that the unavoidable errors in the estimation of the coal should be only a small percentage of the total amount consumed.

Most tests to-day are made with runs of approximately one hundred miles, and this distance is none too great, as there are often about fifty of the one hundred miles which are down grade, and therefore where the throttle is closed.

(*b*) As to the water evaporated, care should be taken, whatever the method pursued, to determine it correctly, and, of course, the amount of priming, or the amount of superheat in the steam that enters the cylinder, should be correctly determined.

(*c*) As to the power developed:

(1) Indicator cards should be taken with sufficient frequency, and all the cylinders should be separately indicated, as it leads to very erroneous conclusions to indicate only one cylinder of a two-cylinder engine, and to assume that the performance of the other is identical with it.

(2) The only way to determine correctly the power developed at the drawbar is by the use of a good dynamometer car. Some of the larger railroads possess such cars, but there are all too few in use.

(*d*) The speed:

When a dynamometer car is employed, the speed can be best determined from its records, but in doing so we must bear in mind that, if we divide the distance travelled in one five-second period by five, the quotient will express the average speed during that five-second period and not the actual speed at any one instant.

In the same way, if we divide the distance travelled during a longer period, the quotient will express the average speed during that period and not the actual speed at any one instant.

These considerations are of special importance in the case of tests to determine train resistance and its variation with speed.

There are numerous speed recorders, some of which can be made to record fairly well, if sufficient care is taken.

Of course, revolution counters should also be used on the locomotive. Many other precautions need to be taken to secure correct results, but they will not be discussed here.

The form in which the results are presented should be such as to enable the reader to grasp them readily, with their variations, and to make comparisons easily. In this connection, the construction of graphical diagrams, for a part of the summaries, is very important.

It is, moreover, the belief of the writer that if suitable care be taken the percentage of errors can be made sufficiently small for practical purposes, and that good road tests furnish much information that can never be obtained from stationary ones.

Rules for road tests have been laid down by many, including the *American Society of Mechanical Engineers*, the *Railway Master Mechanics' Association*, and by individuals who have conducted many such investigations.

Moreover, it is often the case when a railroad is making a series of tests in order to ascertain some special matter, as a comparison of different kinds of coal or to determine a tonnage rating for some special division of the road, that it would cost but little more, in time, energy, and money, to make the test more complete, and to obtain further information, which, though not serving the immediate purposes, may be very much wanted later. To undertake to give even a partial list of the railroads making road tests, would be beyond the scope of this paper. Hence only two sets of such tests will be mentioned here, by way of illustration, and with the object of explaining the nature of the information sought for from them.

These two series both took place during the past year:

A SERIES OF TESTS MADE ON THE PENNSYLVANIA RAILROAD IN 1911.

The main object was to determine the hauling capacity and the economy of four locomotives, viz.:

(1) No. 5075; a 22 inch by 26 inch (80-inch drivers) Atlantic type (4–4–2), using saturated steam, and hand fired:

Total weight	231,500 pounds
Weight on drivers	133,800 pounds

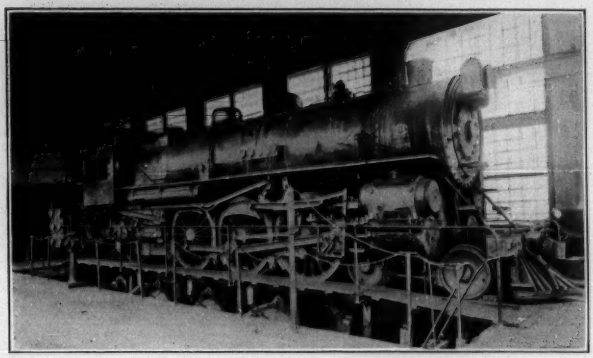
(2) No. 7514; a 24 inch by 26 inch (80-inch drivers) Pacific type (4–6–2), using highly superheated steam, and hand fired:

Total weight	292,000 pounds
Weight on drivers	190,300 pounds

(3) No. 9996; a 24 inch by 26 inch (80-inch drivers) Pacific type (4–6–2), using saturated steam, and stoker fired:

Total weight	272,000 pounds
Weight on drivers	178,500 pounds

FIG. 5.



Locomotive testing plant, Pennsylvania Railroad.

(4) No. 9999; a 24 inch by 26 inch (80-inch drivers) Pacific type (4–6–2), using saturated steam, and hand fired:

Total weight	272,000 pounds
Weight on drivers	178,500 pounds

Fig. 6 shows Locomotive No. 5075. Fig. 7 shows No. 3395, of same type as the other three.

All the runs were made from Fort Wayne to Valparaiso, Ind., a distance of 105 miles. The number of cars used with each engine were 9, 10, 11, 12, 13, and 15, each car loaded weighing about 62 tons.

The coal was weighed and analyzed. The water was measured by a float. The speed was obtained from the records

of the dynamometer car, belonging to the Pennsylvania Railroad, and numbered 495,591. Fig. 8 shows the exterior and Fig. 9 the interior of this car. Indicator cards were, in every case, taken from all the cylinders. The drawbar pull was determined from the records of the dynamometer car.

Besides the above, all other records needed in a complete test were taken, as pressures, temperatures, position of reverse lever, opening of throttle, calorimeter readings, draft pressures, etc.

Of the three Pacific type engines, No. 9999 was adopted as a standard of comparison, and the performances of the others

FIG. 6.

Atlantic type locomotive, No. 5075, Pennsylvania Railroad.

were determined in terms of those of 9999. The arrangement of the work was such as to lead to the determination of the following quantities, among others, viz.:

(1) The coal consumed.

(2) The water evaporated.

(3) The indicated horse-power and the tractive force of the engine.

(4) The dynamometer horse-power and the drawbar pull.

(5) The running speed.

(6) The temperature and pressure of the steam entering the steam chest.

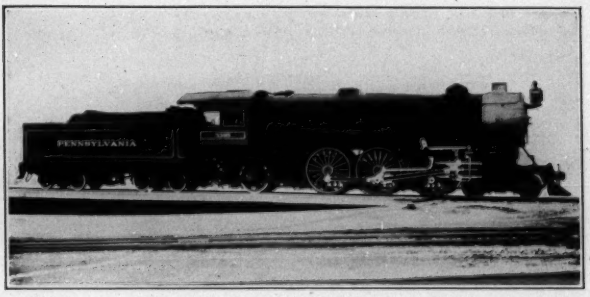
(7) The priming.

(8) The thermal efficiency.

(9) The temperature of the hot gases.

(10) The draft in the fire-box and in the smoke-box.
(11) The amount of smoke.

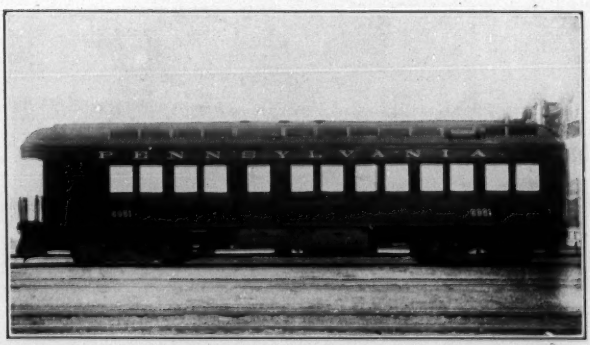
FIG. 7.



Pacific type locomotive, No. 3395, Pennsylvania Railroad.

A study was also made of the effects produced by the use of brick arches and circulating tubes, and many comparisions

FIG. 8.



Dynamometer car, exterior, Pennsylvania Railroad.

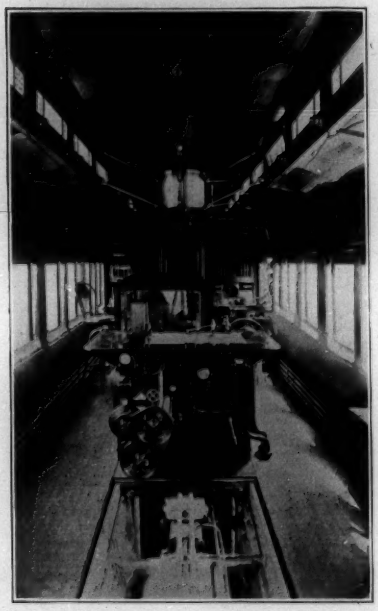
were made of the results obtained with the four engines respectively.

A number of graphical diagrams were constructed, among which were:

(*a*) Curves showing variation of drawbar pull with speed.

(*b*) Curves showing variation of running speed with the number of cars.

FIG. 9.



Dynamometer car, interior, Pennsylvania Railroad.

(*c*) The alignment and grade of the track.

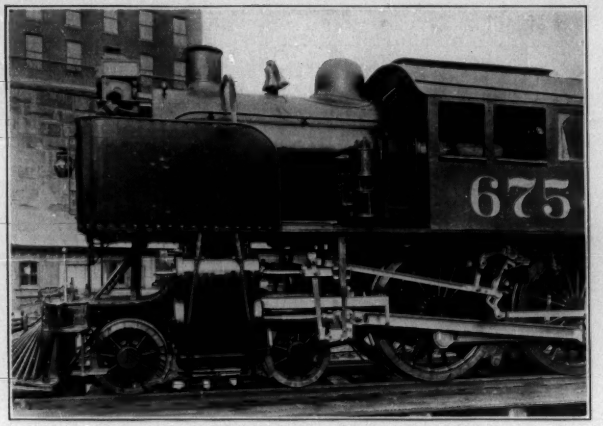
(*d*) The speeds.

(*e*) The time at each station.

(*f*) The direction and velocity of the wind, etc.

Table I gives a summary of some of the more important results of these tests.

FIG. 10.



Pacific type locomotive, No. 675, Philadelphia & Reading Railroad.

FIG. 11.

Atlantic type locomotive, No. 303, Philadelphia & Reading Railroad.

TABLE I.

SUMMARY OF RESULTS OBTAINED IN THE TESTS MADE ON THE PENNSYLVANIA RAILROAD. FORT WAYNE TO VALPARAISO AND RETURN—210 MILES.

No. of engine	No. of round trips	No. of cars	Average indicated horse-power.	Average dynamometer horse-power	Average speed in miles per hour.	Average drawbar pull in pounds.	Average coal per indicated horse-power. Hour. Lbs.	Average coal per dynamometer horse-power. Hour. Lbs.	Average water per indicated horse-power. Hour. Lbs.	Average water per dynamometer horse-power. Hour. Lbs.	Degrees of superheat above boiler steam. (Fahrenheit)
5075	7	9	1645.5	1000.9	64.46	5454	5.316	8.742	27.17	44.66	0
		10	1662.2	995.0	68.00	5442	4.472	7.471	27.39	45.75	0
		11	1511.3	1075.0	63.55	6254	4.708	6.616	29.49	41.46	0
		12	1539.9	1108.1	60.33	6767	4.564	6.343	28.95	40.26	0
		13	1665.1	1150.1	62.43	6830	4.608	6.673	27.66	40.05	0
		14	1782.3	1200.2	58.80	7535	4.346	6.454	26.15	38.83	0
		15	1686.6	1205.5	56.70	7863	5.911	7.011	27.09	37.90	0
7514	6	9	1843.6	1133.8	69.09	5933	3.008	4.892	20.17	32.80	235.3
		10	1882.9	1112.8	69.61	5875	2.925	4.950	18.84	31.88	
		11	1768.3	1165.3	65.60	6532	2.795	4.242	20.00	30.35	199.3
		12	1745.7	1171.4	66.98	6446	2.992	4.459	19.53	29.11	209.8
		13	1717.0	1162.4	62.51	6816	2.917	4.308	20.03	29.59	214.7
		15	1953.1	1334.0	62.78	7853	2.844	4.164	19.45	28.48	220.6
9996	7	9	1459.1	846.3	60.42	5178	3.747	6.462	26.63	45.92	0
		10	1307.7	780.7	57.78	4983	3.687	6.343	28.80	48.24	0
		11	1401.4	838.0	57.06	5420	3.949	6.605	28.12	47.02	0
		12	1548.5	992.6	57.43	6366	4.310	6.724	27.97	43.64	0
		13	1683.3	1100.9	57.59	7063	4.822	7.373	26.08	39.88	0
		14	1694.9	1139.0	56.80	7440	4.858	7.237	26.84	39.94	0
		15	1723.9	1179.2	55.54	7884	4.849	7.091	26.77	39.00	0
9999	6	9	1419.8	795.0	61.23	4737	3.539	6.321	30.06	53.69	0
		10	1447.3	850.3	60.33	5201	3.736	6.361	29.33	49.92	0
		11	1571.5	955.2	60.18	5855	4.373	7.194	27.77	45.68	0
		12	1687.8	1021.6	59.59	6263	4.006	6.618	28.46	47.02	0
		13	1785.0	1099.7	54.63	7379	3.662	5.943	26.51	43.03	0
		15	1697.2	1165.1	54.46	7907	4.373	6.378	27.63	40.25	0

A SERIES OF TESTS MADE FOR THE PHILADELPHIA AND READING RAILROAD BY THE BALDWIN LOCOMOTIVE WORKS IN 1911.

The main object was to determine the hauling capacity and the economy of four-passenger locomotives, viz.:

(1) No. 675; Three-cylinder 19 inch by 24 inch (74-inch drivers) Ten-Wheel type (4–6–0) locomotive, using steam of a low degree of superheat, and hand fired:

Total weight of engine and tender..... 178 tons

(2) No. 300; Three-cylinder 19 inch by 24 inch (80-inch drivers) Atlantic type (4–4–2) locomotive, using steam of a low degree of superheat, and hand fired:

Total weight of locomotive and tender..... 172 tons

(3) No. 301; Two-cylinder 22 inch by 26 inch (80-inch drivers) Atlantic type (4–4–2) locomotive, using steam of a low degree of superheat, and hand fired:

Total weight of locomotive and tender..... 170 tons

(4) No. 302; Two-cylinder 22 inch by 26 inch (80-inch drivers) Atlantic type (4–4–2) locomotive, using saturated steam, and hand fired:

Total weight of locomotive and tender..... 170 tons

Fig. 10 shows the first of these locomotives. Fig. 11 shows No. 303 of the same type as the other three.

All the runs were made, in regular service, from Philadelphia to Jersey City, express, and return local, the distance each way being about 90 miles.

The average number of cars hauled was eight, the total weight of train in tons being: For No. 300—633.8; for No. 301—628.7; for No. 302—629.9; and for No. 675—617.

The coal was weighed and analyzed.

The water was measured by means of four water glasses, one at each corner of the tank.

The speed was obtained from the records of the dynamometer car belonging to the Pennsylvania Railroad, numbered 495,591.

Indicator cards were taken from all the cylinders at intervals of three minutes or less.

The drawbar pull was determined from the records of the dynamometer car.

Besides the above, all the other observations necessary for a complete test were taken, as pressures, temperatures, position of reverse lever, opening of throttle, calorimeter readings, draft pressures, etc.

The arrangement of the work was such as to lead to the determination, among others, of the following quantities:

(1) The coal consumed.
(2) The water evaporated.
(3) The indicated horse-power and the tractive power of the engine.
(4) The dynamometer horse-power and the drawbar pull.
(5) The running speed.
(6) The temperature and the pressure of the steam.
(7) The priming.
(8) The temperature of the hot gases.
(9) The draft in the smoke-box.
(10) The amount of smoke.

Graphical diagrams were constructed, on which were recorded:

(*a*) The make-up of the train.
(*b*) The location where cards were taken.
(*c*) The throttle opening.
(*d*) The cut-off.
(*e*) The boiler and steam-chest pressures.
(*f*) The superheat, based on steam-chest pressure.
(*g*) The superheat, based on boiler pressure.
(*h*) The draft, and the temperature in the smoke-box.
(*k*) The speed.
(*l*) The tractive force of the engine.
(*m*) The drawbar pull.
(*n*) The profile of the road.

Table II gives some of the more important results of these tests.

TABLE II.

SUMMARY OF SOME OF THE RESULTS OF THE TESTS MADE ON THE PHILADELPHIA AND READING RAILROAD BY THE BALDWIN LOCOMOTIVE WORKS. PHILADELPHIA TO NEW YORK—90 MILES.

No. of engine	No. of trips	No of cars	Average indicated horse-power.	Average dynamometer horse-power.	Average speed in miles per hour.	Average drawbar pull in pounds.	Average coal per indicated horse-power. Hour. Lbs.	Average coal per dynamometer horse-power. Hour. Lbs.	Average water per indicated horse-power. Hour. Lbs.	Average water per dynamometer horse-power. Hour. Lbs.	Degrees of superheat above boiler steam. (Fahrenheit)
675	3	8	1360	857.0	57.40	5414	4.50	7.13	28.0	44.36	51
		8	1293	816.7	54.93	5513	4.48	7.10	27.9	44.22	0
		8	1261	820.4	54.91	5536	4.36	6.57	27.8	42.58	60
300	5	8	1343	870.0	56.00	5730	4.70	7.28	24.2	37.48	65
		8	1162	850.0	56.70	5550	5.52	7.54	28.8	39.60	65
		8	1377	943.3	56.81	6120	4.52	6.66	25.0	36.46	61
		8	1312	909.6	55.10	6180	5.22	7.36	24.6	34.74	71
		8	1386	945.5	56.60	6120	5.42	7.96	23.7	34.79	66
301	3	8	1319	889.4	57.14	5700	4.52	6.71	24.3	36.54	41
		8	1211	869.4	54.30	5910	4.98	6.98	27.7	38.89	51
		8	1155	870.0	53.38	5970	5.35	7.10	29.1	40.61	46
302	3	8	1414	857.6	56.20	5640	4.51	7.21	24.8	39.85	0
		8	1264	868.8	53.74	6000	4.75	6.91	26.0	38.99	0
		8	1133	892.5	57.32	5760	4.81	6.06	33.4	42.12	0

The figures in Tables I and II are published by kind permission of Mr. S. M. Vauclain, Vice-President of The Baldwin Locomotive Works, Philadelphia, and of Mr. A. W. Gibbs, Chief Mechanical Engineer of the Pennsylvania Railroad.

NATURAL GAS, WITH INCIDENTAL REFERENCE TO OTHER BITUMENS.*

BY

I. N. KNAPP, M.E.,

Consulting Engineer.

This storing process could not, of course, go on indefinitely, since the new reservoir would require additional pressure to force the gas further and further back in the rock, and the conclusion was reached that in time the rock pressure of the well would show a large increase, and that the gas, being thus stored up in natural reservoirs, would be available for future consumption. This conclusion was subsequently verified.

West of Chanute, Kansas, I completed [50] a gas well in February, 1903, that gave about four million cubic feet open flow capacity and 315 pounds closed pressure, and gave dry, clean gas. I left the well closed in. Soon after a boom company drilled a well one-quarter of a mile north and got some oil above the gas. This well was allowed to stay open for weeks, wasting the gas, presumably to make an oil showing to sell stock with.

In December, 1903, my well showed 275 pounds closed pressure, and about one million cubic feet open flow, and some salt water. No other wells were then within a mile or more of these two.

These examples show the migratory and elusive character of gas in porous rocks.

At Chanute I used, for a few months, the natural gas under rock pressure from two wells for blowing or pumping oil wells and pumping from field tanks. I then put in gas engine driven air compressors to supply compressed air for the same operations.

The rock pressure of the two wells had fallen from 305 to 125 pounds, and the gas then showed wet. I hitched these two wells on my air line as air receivers or compensators and restored the rock pressure to 290 pounds of air and drove back

* Continued from page 498.

[50] Drilled about the centre of N. W. ¼ Sec. 24-27-17.

the salt water. In this way I could, for a while, use compressed air to many times the capacity of my compressors; also, I could shut down my compressors without affecting my field operations. This shows what, I believe, was a new use for a reservoir rock.

SECTION VI.

NATURAL GAS SANDS.

Any porous or reservoir rock in a horizon where paying pools of oil or gas occur is called by the drillers a "sand," whether it be a sand or a limestone rock. When this "sand" is drilled into and oil or gas, or both, are found in paying quantity, it is called a "paying sand," and if not found in paying quantity the well is said to be a "dry hole" or a "duster," and the sand is said to be "dry," although it may be heavily charged with salt water.

The popular idea is that both oil and gas are found in one large cavern [51] or in several connected together in a sort of underground stream.

This is a great mistake, for crevices in oil and gas rocks, especially where they lie deep below the surface, are of rare occurrence.

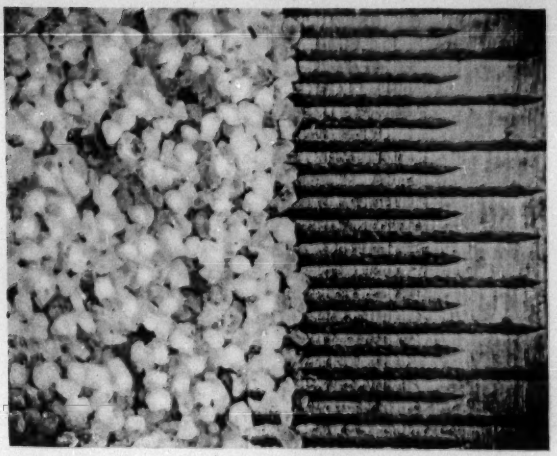
The drillers oil and gas sands are rocks that are pierced with millions upon millions of minute connected pores, which may readily be observed with a good microscope magnifying to from twenty to thirty diameters. When such rocks are saturated with oil or filled with gas under pressure they become the paying pools and fields of oil and gas. Geologically speaking, the oil and gas rocks are identical and have a common origin. Pools of natural gas are much more generally distributed and occupy a larger area than the oil pools.

Oil always has more or less gas associated with it, in the same porous rock in all classes of accumulations; but, on the contrary, gas occurs in fields and pools entirely separate and free from oil and in porous strata by itself.

When an oil well is shot, pieces of saturated rock are some-

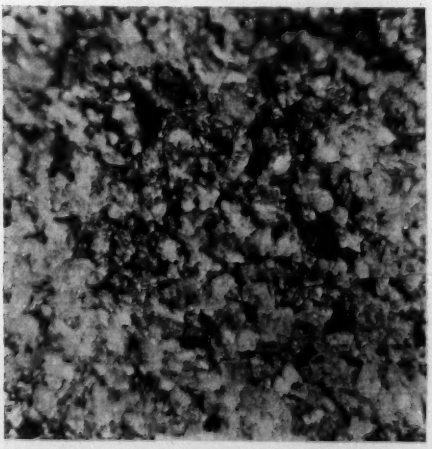
[51] West Virginia Geological Survey, vol. i (a), p. 45. Eleventh Annual Report U. S. Geological Survey, part i, p. 657. Penna. Second Geological Survey, vol. iii, p. 247.

FIG. 9.



Sand held on No. 80 sieve but passed a No. 40 sieve. The dimensions shown are $\frac{1}{100}$ of an inch, Brown & Sharp rule.

FIG. 10.

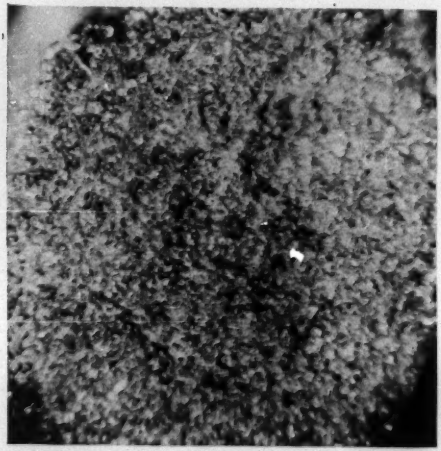


Gas sand from a 34,000,000-foot well on the B. Johnson farm, south of Independence, Kansas. A coarse, open sand; little cementing material.

times thrown out. An immediate examination of such pieces often shows a bubbling and hissing caused by the escape of oil and gas from the pores.

Fig. 9 is a microphotograph,[52] on a scale of twenty to twenty-five diameters, of a loose sand held on a No. 80 sieve but passed by a No. 40, and the divisions shown are spaced

FIG. 11.



Chanute, Kansas, gas sand from a well. Fine, close sand with much cementing material. A 3,000,000-foot well.

one one-hundredth of an inch. This has no cementing material, and its pore space[53] is probably 38 to 40 per cent.

Also, on the same scale, have been made a number of microphotographs of specimens of oil and gas rocks, or sandstones and limestones, commonly called "producing sand."

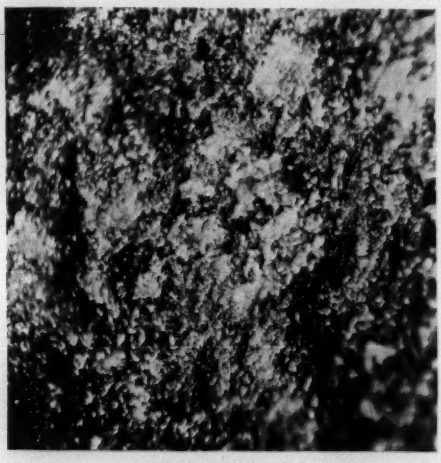
Fig. 10—Specimen of sand from B. Johnson well, south of Independence, Kansas. It came from a well giving an initial open flow capacity of 34,000,000 cubic feet per 24 hours. It is coarse grained, with little cementing material and a rich gas sand.

[52] Microphotographs made under direction of Mr. C. O. Bond.
[53] U. S. Geol. Survey, 19th Annual Report, table p. 91.

Fig. 11—Specimen of sand from Chanute, Kansas. It is from a well that gave 3,000,000 cubic feet initial open flow capacity, and is a fine-grained rock with average amount of cementing material.

Fig. 12—Specimen of the Trenton limestone from northwestern Ohio. It was given me as a fair specimen of the top of the producing sand.

FIG. 12.



Top of Trenton rock, N. W. Ohio gas field. Coarse open limestone rock.

Fig. 13—Specimen of the Onondague limestone from the Kent gas field, Ontario, Canada. This is a fair gas-producing sand; the wells measure from 500,000 to 6,500,000 initial open flow capacity, and hold up good.

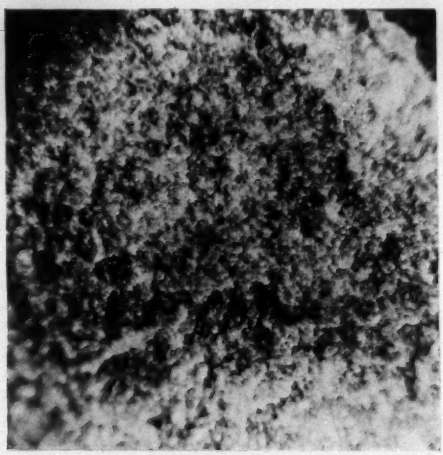
Fig. 14—Specimen of gas sand from a well in the Caddo, Louisiana, field that measured 82,000,000 cubic feet open flow capacity per 24 hours. This is a very fine grained sand. A close examination under the microscope shows it is high in pore space, probably one-third. It is a very friable and soft sandstone.

Fig. 15—Specimen of gas sand from Terrebonne Parish,

Louisiana. This is a very soft stratified sandstone from a well that blew out and was lost, but the specimen has all the characteristics of a true gas sand. This is believed to be from the Quarternary system, so, geologically speaking, is of very recent origin.

Fig. 16—Specimen of salt from Belle Isle, Louisiana. (Specimen taken by Mr. A. C. Veatch and photographed by U. S. Geological Survey.) This is extremely interesting, as it

FIG. 13.



Onondague limestone from the Kent gas field, Ontario, Canada; fine-grained rock

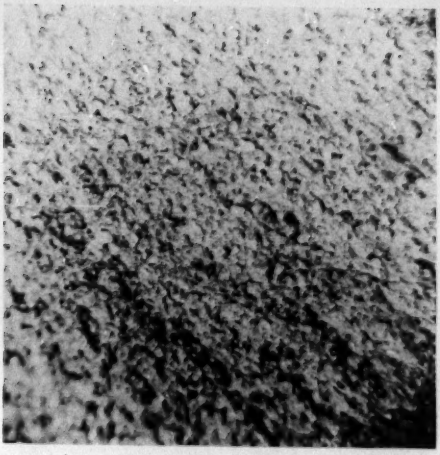
shows globules of oil and gas imprisoned in the salt, and the connected porous condition necessary for the production of oil and gas does not occur.

Sandstones[54] have a porosity of 10 to 38 per cent., depending on the amount of cementing[55] material deposited from solution in the interstices of the original sand through the agency of ground waters.

Limestones have a greater range of porosity than sand-

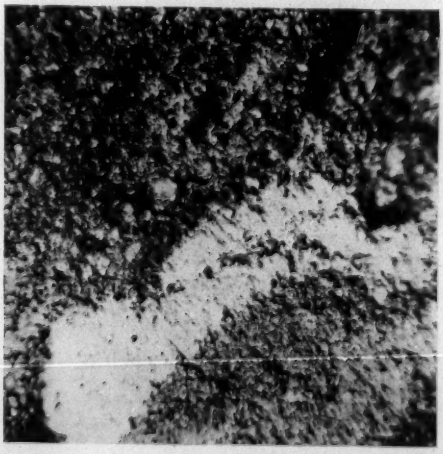
[54] U. S. Geol. Survey, 19th Annual Report, table p. 91.
[55] U. S. Geol. Survey, Water-Supply and Irrig., paper No. 67, p. 17.

FIG. 14.



Caddo, La., gas sand; from an 82,000,000-foot well. Very fine grains, lightly cemented. Must be one-third pore space.

FIG. 15.

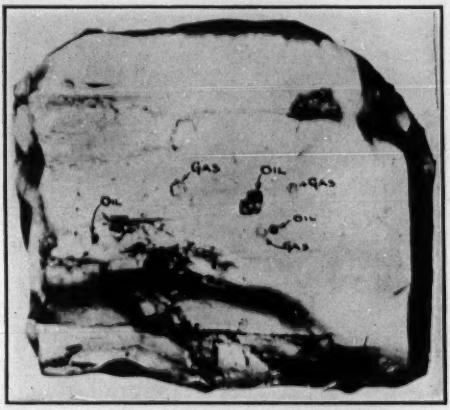


Terrebonne Parish, La., gas sand. This sand is from Quarternary material, and so is, geologically speaking, way up on top above any productive gas sand. Material soft and no well yet saved in it.

stones. Some have a natural porosity due to their fossiliferous character. Some have been changed chemically, causing recrystallization in smaller forms, reducing the space occupied, and thus causing porosity. Some porosity may have been caused or enlarged by dissolving action of circulating ground waters both in limestones and sandstones.

At Belle Isle, Louisiana, I drilled in one very porous limestone stratum that may have been one-third pore space and was full of sulphur water, but occupied relatively the same position

FIG. 16.



Belle Isle, La., salt impregnated with oil and gas. Specimen taken by Mr. A. C. Veatch and photographed by U. S. Geological Survey.

to the salt and sulphur as the productive oil rock at Spindle Top.

According to Carll,[56] experiments in a crude way show that the porosity of the oil- and gas-bearing sandstones of Pennsylvania is from one-tenth to one-fifteenth of their bulk, and might even hold one-eighth under normal conditions. White[57] puts the proportion of pore space in a fairly good producing oil- or gas-bearing sandstone in West Virginia at from one-fifth

[56] J. F. Carll in Pa. Second Geol. Survey, vol. iii, pp. 251–253.
[57] I. C. White, in W. Va. Geol. Survey, vol. i (a), p. 45.

to one-tenth. The limestones are more variable in porosity, but it is fair to assume one-tenth as the average.

Assuming a pay streak ten feet thick and an available porosity of one-tenth, we would have one foot in depth of oil, or 43,560 cubic feet, or about 7,500 barrels per acre. This is probably better than the average per acre yield in any one horizon of the Paleozoic rocks of the United States. Three thousand barrels per acre was fully as much as the yield in Kansas, where I operated.

Rocks of the same porosity filled with gas at 30 atmospheres (450 pounds) would hold 1,300,000 cubic feet per acre; or a gas well flowing at the rate of 1,300,000 cubic feet per 24 hours from a rock pressure of 30 atmospheres would relieve as much pore space as a well flowing 7,500 barrels of oil in the same time. By pumping, the gas may be exhausted down to or below atmospheric pressure and thus at least 95 per cent. of the gas produced. It is doubtful if over 75 per cent. of the oil in a sand is obtained in any case.

The total production of natural gas in the United States is now around 500,000 millions of cubic feet per year. If this gas had originally the assumed average rock pressure of 30 atmospheres, it would require a pore space of 16,666 millions of cubic feet to contain it. The same space filled with oil (1 barrel = 42 gal. = 5.6146 cubic feet) would hold 2,968 millions of barrels, or more than the total production of oil in the United States from the beginning to the present time.

Using our estimated yield of 1,300,000 cubic feet of gas per acre from the assumed 10 feet of 10 per cent. pay sand, it would require about 600 square miles of such a sand to supply a year's consumption of natural gas in the United States.

The figures assumed are tentative and an approximate to the actual.

The original [58] natural-gas field in Indiana occupied an area of 2,850 square miles of almost continuous territory of the Trenton rock. The initial rock pressure in 1886 was 325 pounds to the square inch.

At the end of 1902 this pressure had declined to an average of about 50 pounds, which represents only 15½ per cent. of the original volume.

[58] Production of Natural Gas 1902, Mineral Resources of the U. S., p. 36.

This field was exhausted at the rate of about 175 square miles per year. Properly conserved for domestic use, not over twenty square miles would have been used per year.

SECTION VII.

DRILLING GAS WELLS.

The art of drilling wells in solid formations with a cable and percussion tools for water, brine, and to prospect for minerals is many hundreds of years old. Formerly it was a very difficult, tedious, and expensive operation to drill a deep well, but now one can be sunk 2,000 to 3,000 feet at a moderate cost and in a comparatively short time. The methods of drilling and tools employed are practically the same in drilling for water, oil, or gas.

It took the city of Charleston, S. C., twelve years (1846 to 1858) to sink an artesian well to a depth of 1,260 feet and at a cost of over $30,000. The flow obtained was thirty gallons per minute.

In the same city, in the early part of 1911, an artesian well was sunk 2,007 feet in 92 working days of ten hours each, at one-third the above cost. The flow obtained was 450 gallons per minute.

The development of the Pennsylvania oil and gas fields gave a great impetus to the art of drilling with cable tools in solid formations.

It took Colonel Drake from May 20th to August 28th, 1859, to get in 36 feet of drive pipe to bed rock, drill 33½ feet (total 69½ feet), and bring in the first oil well.

I have had two men put in a joint (20 feet) of 8¼-inch drive pipe and drill to 70 feet in one tour of twelve hours.

In Colonel Drake's day a man could carry a string of cable tools on his shoulder. Now it is not uncommon to use an auger stem weighing 2,000 to 2,500 pounds and a string of tools weighing between 4,000 and 5,000 pounds.

Soon after the Burning Springs, West Virginia, oil development began, in 1860, the drilling craze spread all over that State. Many wells were drilled, or at least attempts were made to drill them, which nearly always ended by getting the tools fast and the hole plugged, because the operator had not

then learned the art of dealing successfully with rocks that crumble, or cave, and fall into the hole when water touches them. The consequence was drilling for oil and gas was confined to those districts in Pennsylvania and West Virginia where the walls of the wells stand firm after the holes are drilled, even though drilled "wet" and full of water from top to bottom.

It took about thirty years to learn how to drill the softer West Virginia rocks with the standard tools. (See page 147, West Virginia Geological Survey, vol. i.)

The development following the drilling of the Lucas well, near Beaumont, Texas, gave a great impetus to the hydraulic rotary method of drilling.

In the hydraulic rotary method of drilling, a 4-inch drill pipe weighs 11¾ pounds per foot, so at 3,000 feet its weight becomes over 17 tons. This method is a rapid one for drilling soft formations, and has a record of making 1,065 feet in thirty-two hours in an oil well at Corsicana, Texas, but it is an extremely unsatisfactory method to use in prospecting for gas, because of the water pressure employed to flush the cuttings from the hole and the necessity of thickening the water with clay to sustain the walls of the well in very soft stuff, and should not be employed, except, of course, where it is not possible to drill with cable tools.

I know that I failed to satisfactorily use the hydraulic rotary method in wells in very soft ground, where I got indications of oil and gas, and do not know whether the oil and gas were present in paying quantities or not. Also, I drilled through rich gas-bearing strata in two wells without the gas showing or giving any indication of its presence, and these wells were accidentally lost by blowing out, and they then both showed for better than 20,000,000-foot wells before they caved in and shut off.

In drilling with the cable tools a casing is set below all water-bearing strata and above the gas sand, and the well bailed dry and the casing proved to be tight. Drilling is continued with only enough water to "mix the mud"—that is, so the cuttings can be made in condition to be bailed from the hole as often as necessary. In solid formations a gas well seldom comes in suddenly. As the sand is approached in drill-

ing, gas will begin to bubble in the hole. When a large well (10,000,000 or better) is expected so it will require to be shut in the casing, it is best at this time to put a valve on and close the well in and subject it to rock pressure. This may be done quickly by connecting in a nearby well or pipe line and thus test the valve and casing and prove they are in good working condition.

On further drilling, as the well develops volume, it will throw the mud out of the hole. Sometimes the expansion of the gas will freeze the mud and stick the tools, but they soon thaw out. Also, the mud on the tools and walls of the well, when conditions happen just right, will roll into balls the size of coarse shot or marbles, and the drillers will say they have a "pebble sand." After the real productive sand is reached and you have a good gasser the well will "drill itself in" and the tools will float and sometimes come up the hole faster than the cable can be pulled out.

In the smaller wells it may prove best to tube and pack them.

Time forbids I should enter into more detail of the drilling art. The supply dealers' catalogues show a wealth of tools and appliances. To successfully drill, care for, and produce from gas wells requires experience, skill and good judgment, and can best be learned by actual experience. It is a skilled trade or art that experience only can teach.

SECTION VIII.

DEVELOPMENT OF THE NATURAL GAS INDUSTRY.

Our historical account shows that early in the last century in the United States drilling wells in search of brine to get that prime necessity of life—common salt—natural gas in quantity was found and put to a limited use. The tools and method of drilling thus evolved were later (1859) employed by Colonel Drake in drilling the first well ever drilled in search of oil.

The successful outcome of this venture gave birth to the petroleum industry, and its development, in turn, incidentally showed Nature's great stores of that perfect fuel, natural gas.

At first the gas associated with the oil from oil wells was regarded as a dangerous nuisance, and carefully led away from the well in pipes and burned to get rid of it.

After a little, however, this casing head gas began to be used for fuel under the boilers in drilling and pumping oil wells and for light and fuel in the immediate vicinity of the wells.

The proportion of gas thus produced that reached actual [59] use was formerly very small. Recently such gases have been liquefied and gasoline and other products profitably produced.

Burning Springs,[59a] West Virginia, now a village of 250 inhabitants, was, in the spring of 1861, a boom town of 6,000, "every part of which was rendered brilliant by mains filled with natural gas."

During the '60's, in wildcatting for oil, wells producing natural gas only were found. Little, if any, attempt was made to utilize this gas, and the production was allowed to waste into the air. From such wells the "dry gas" of commerce is produced and distributed for light, heat, and power.

The Leechburg [60] gas well was drilled in 1871 for oil, but proved a strong gasser with salt water and was allowed to blow for some months. It was bought by Rogers & Burchfield, a separator put in to take out the water, and the gas put in use in their iron works in April, 1873, for heating and puddling iron, and was the first gas to be so used.

The Newton well, on the Nelson farm, 5¼ miles northeast of Titusville, Pa., was finished in May, 1872. It measured 4,000,000 feet open flow and had a closed pressure of 350 pounds. The well was purchased by Mr. Henry Hinkly, who put in a two-inch line to Titusville and delivered gas to that city August 1, 1872.

The two-inch line was too small, and a 3¼-inch was laid, and at the close of the year 250 consumers were using gas for heating and lighting.

Titusville thus had the first natural-gas plant which supplied light and heat in a large and permanent quantity by methods and appliances that are practically the same as those used to-day, and it is looked upon as the beginning of the natural-gas industry that has since assumed such large proportions.

[59] Technical paper 10, Department of the Interior, Bureau of Mines.

[59a] West Virginia Geol. Survey, 1911, p. 8.

[60] Henry's "Early and Later History of Petroleum," p. 208.

In 1873 there were numerous localities [61] in Venango, Butler, and Armstrong Counties, Pennsylvania, in which natural gas was introduced and successfully used for fuel and light.

In 1875 a 17-mile 6-inch gas line was built from Butler County to Etna, near Pittsburgh, and the gas utilized at the iron mill of Spang, Chalfant & Co. for a number of years with great success.

The Haymaker well,[62] at Murrysville, was drilled in 1877. This wasted gas to the equivalent of 1,000 tons of coal per day for five years.

It was not until 1883 that this great storehouse of potential energy was made useful by Pew & Emmerson, who laid a pipe line to Pittsburgh and supplied consumers. By the close of 1883 several pipe lines were supplying gas for domestic use and to manufacturers of iron, steel, and glass in the Pittsburgh district.

In June, 1884, the celebrated Westinghouse [63] well came in, and this greatly accelerated the natural-gas industry, which rapidly reached enormous proportions in the Pennsylvania fields, and, as this field weakened, lines were extended into West Virginia.

The value of natural gas having now been fully demonstrated to capital, a large amount of money was thus made available for investment in gas territory, gas wells, and pipe lines.

In November, 1884, the first high-pressure gas was found in the Trenton limestone in Ohio, at Findlay. It was put to domestic use the following year.

On January 20, 1886, the Karg well was struck, and from this on the development of that district was rapid.

These large productions of gas and oil from the Trenton [64] (Lower Silurian) limestone were entirely unexpected. It would be hard to say whether the geologist or the producer was most surprised by these results. No one suspected it, or at least no one had prophesied it.

[61] "Production of Nat. Gas, 1902," by Oliphant.
[62] Mineral Resources U. S., 1885, p. 177.
[63] Am. Inst. Mining Engineers, vol. xiv, p. 668.
[64] Dr. Orton, Geol. Survey of Ohio, 1890, p. 106.

The Kokomo [65] No. 1 well developed an open flow of 2,000,000 feet in October, 1886, and from this dates the development of the Indiana field, which also took place with great rapidity.

With these remarkable and sudden discoveries of such quantities of natural gas that were heretofore unknown the impression became general that the reservoirs of this best of Nature's fuels were inexhaustible.

The climax [66] was reached in 1888, when it is estimated 750,000 millions of cubic feet of natural gas was consumed and wasted in the Pennsylvania and Trenton rock fields.

In 1882, in drilling for oil seven miles northeast of Paola, Kansas, natural gas was developed.

In 1884 a franchise was obtained from that city, which has ever since been supplied with gas from this immediate vicinity.

In 1892 Coffeyville was supplied with natural gas; then Cherryvale and Independence in 1893; Neodesha and Iola in 1894; Humboldt in 1895. Chanute was supplied in 1896 from a well 16 miles west of town by the Prairie Oil and Gas Company.

The coming in of the Lucas well, near Beaumont, Texas, in January, 1901, gave a great boom to wildcatting for oil in the mid-continent (Kansas-Oklahoma) field. Hundreds of companies were formed and an immense amount of wildcat work done, and by the mid-year of 1902 oil and gas enough were shown to attract experienced operators.

The production of oil in the mid-continent field was 81,186 barrels in 1900, and 49,459,739 barrels in 1910.

The production of natural gas was unquestionably proportional, but there are no figures to give it in cubic feet.

During 1905 a large consolidation of gas companies took place in Kansas. Extensive pipe lines were laid in eastern Kansas, extending into the Joplin district, Missouri, and many additional cities supplied with natural gas.

During 1906 gas-pumping stations were completed and gas supplied to Kansas City and St. Joseph, Mo., and other places. Also, Oklahoma developed some large gas wells and some twenty towns and cities were supplied during this year.

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[65] Mineral Resources of U. S., 1886, p. 509.

[66] Mineral Resources of U. S., 1902, Production of Natural Gas, p. 10.

Since 1906 an immense amount of gas has been developed in the mid-continent field, and a population of over 1,000,000 is now served with gas for domestic consumption from it. Additional gas-pumping stations have been put in and pipe lines extended, but no new areas of importance have been added to the field.

Professor Haworth,[67] in a recent report (November, 1911), states that from two to three years, under present conditions, is as long as natural gas may be expected to be delivered to Kansas City, Missouri.

During the year 1905 a new gas area was opened near Caddo Lake, north of Shreveport, La.

In 1907 Shreveport, Texarkana, and a number of smaller places piped for gas.

The Caddo field now supplies natural gas as far north as Little Rock, with branch lines to many towns; also to towns and cities in Texas.

The companies planning to pipe natural gas to St. Louis and New Orleans from the Caddo field have apparently abandoned their projects.

Some gas has been developed in Texas.

A promising field has been found in western Alabama. It is impossible to say what stores of natural gas Nature has hidden away for future use.

It is probable the best fields contiguous to populous or manufacturing centres are known and have been exhausted or seriously depleted.

That there will be great fields developed in the United States in the future I do not doubt, judging from the past, but it is dangerous to prophesy of them.

Time will not permit me to speak of pipe lines, compressing stations, appliances for distribution, combustion, and details of the various uses of natural gas, nor to take up the matter of its possible chemical value.

[67] See "An 'Expert's' Opinion on Gas," *Oil and Gas Journal*, November 30, 1911.

SECTION IX.

PROPER USE OF NATURAL GAS.

Some years ago (1897) Dr. Edward Orton made investigations for the State of New York on petroleum and natural gas. Dr. Orton was an eminent geologist, a man of many accomplishments, and one of the most honorable and lovable of men. He has since passed away. I cannot do better than to quote his words on the "Proper Use of Natural Gas." Dr. Orton wrote as follows:

"Natural gas is the best fuel known to man. No advance beyond it is possible, but to secure the best results some scientific knowledge is required in regulating its combustion. Since it is the perfect fuel, it admits of application to almost every purpose to which fuel can be turned. The principal exception is in the manufacture of iron from its ores and in other similar metallurgical processes. In the working of iron on rolling mills, forges, and foundries, and in the production of steam for all its multifarious applications, in the direct use of heat, in the manufacture of glass and cement, in the burning of pottery, tile, and brick, it is, as before said, the perfect fuel. It effects important economies and greatly improves the quality of production at the same time. But superlatives in describing its advantages and value ought to be reserved for its use as a household fuel. It is here that it does the greatest good to the greatest number. It lightens and simplifies the labors of housekeeping to a surprising extent.

"The truth is that natural gas ought to be exclusively confined to domestic use. It is too good for any other line of service, too fine a product for the coarse applications already named. It is a profanation of the good gifts of Nature to use gas in burning bricks and tile, in calcining limestones, in generating steam, in the manufacture of glass or cement. There is not enough of it anywhere for manufacturing purposes. The most prolific districts for its supply thus far known in the world have been exhausted in a single decade.

"The amount of gas required in manufacturing necessitates the speedy decline and failure of every gas field, even the greatest.

"Iron working demands by far the most lavish and unwarrantable use of gas of all manufacturing industries. A

rolling mill will range from 1,000,000 to 5,000,000 feet a day. How far will a million feet go in the support of household use? A house of 12 rooms, using gas in cooking, range, laundry, furnace, and in six grates, uses on an average for the year about 40,000 cubic feet a month, or 1,333 feet a day. One million feet would supply 750 such establishments, or what the smallest rolling mill would use in a day would serve such a home for more than two years. But, instead of using 1,333 feet a day, the average residence will find all its necessities met by less than one-half the amount named. Five hundred feet will make an ample daily supply for the majority of city or village homes. For such use the amount consumed in the smallest rolling mill in a day will serve 2,000 ordinary residences for the same length of time, or would serve one such dwelling for 2,000 days. A ten-pot window-glass factory uses what would supply 1,200 dwellings for an equal length of time.

"The sacrifice of human comfort and well-being to business greed finds a striking illustration here, and cannot be too emphatically condemned. The application of natural gas to manufacturing uses necessarily involves such a sacrifice.

"*Whoever has occupied for a year a dwelling adequately supplied with natural gas will recognize so many and so great additions that it makes to the comfort of life that he will not insist on a very close balance of expenditures and credits in dealing with this subject.*

"When applied to manufactures it is doubtful whether natural gas works in the interests of the general good. It is true that the cost of manufacture is cheapened and the quality of the production is likely to be improved by its introduction. But the fortunate manufacturer who can avail himself of it at once begins to undersell his competitors who are working under the old conditions, because his fuel, which is often the most costly element in his business, costs him nothing. In this way the most prudent manufacturer carrying on his business in the old way may find himself forced to the wall. Competition for him is simply impossible till the storm is past. Meanwhile the manufacturer who uses natural gas finds his business greatly improved in volume for the time being, because of the discouragement and failure of his natural competitors.

"Such a state of things is not good for any community.

It is much worse when the towns that find gas within their reach invite in manufacturers by municipal grants and the like. Factories come to be established, far from all supplies of essential materials with the one exception of fuel. As soon as fuel fails, the factory is bound to disappear. In many such cases the last state of the town is worse than the first.

"One of the evil results of the use of natural gas in manufactures is the development of the speculative fever called a 'boom' in the towns that find gas at hand. Real estate feels the effect soonest. Inflated values derange legitimate prices, and the reactions that are inevitable are always hurtful.

"The proper use of natural gas—*i.e.*, household use—is the only one that can bring adequate return to the company undertaking to supply it. It is a source of satisfaction to find that the true use pays best.

"*The price of gas ought to be increased in every community that is now using it. There is no good reason why it should be sold at any less price than the fuel which it displaces, or, in other words, why the better article should be sold for less than the inferior.* In computing the cost of the displaced fuel, account should always be taken of the various items involved, such as its storage and preparation, the cost of lighting fires, and the expenses of removing ashes and cinders, none of which enter into the use of gaseous fuel. It may be urged that an increased price for gas would result in extravagant profit for the gas companies. It cannot be denied that there is a possibility of such a result, but, as a matter of fact, there are very few cases in the country in which companies have got back their original investment or see any good chance of getting it back. They are generally obliged to content themselves with generous dividends while the gas is in full flow." (See *Bulletin of the N. Y. State Museum*, vol. 6, No. 30, November, 1899, p. 483.)

SECTION X.

SUMMARY.

For ages the human race has known of natural gas through its surface indications, but the great storehouses of this best of Nature's fuels were unknown and unsuspected until about two generations ago, when by accident the drill of the brine- and

oil-producer revealed their presence; and of the vast quantities of gas thus unlocked, the door was at first left wide open for its wasteful escape.

Only forty years have passed since there was effort made to control and utilize this valuable fuel, and it has been too often regarded as a by-product of the oil fields of no special value.

We have learned that porous rocks under proper conditions act as reservoirs or storehouses for oil and gas. When by force we break into them with the drill we find the invisible and practically inodorous gaseous contents under great pressure, and so peculiarly elusive and migratory. If the drill hole be not well guarded it will flee to other places, and, if left open to the air, will escape and be lost.

It is largely because of these characteristics—invisibility and self-escape—that the amount lost is not appreciated. This mobile or migratory condition of oil and gas is reflected in legal decisions.

The Supreme Court[68] of Oklahoma, in a recent decision, "held that oil and gas cannot be sold in the ground, but simply the right to use what comes to the surface. Coal and other minerals go with the ground, as they are part of it, but oil and gas, while of the earth, are not earth, and while oil land can be leased or sold and the oil itself sold after it comes to the surface, it cannot be transformed until after it is out of the ground."

The same rule applies to gas.

If oil and gas were of such a nature they would remain in place like coal we would not have such hard problems to solve in the production of oil, and particularly that of natural gas.

After they are once discovered in paying quantity it is impracticable, under present conditions, to hold them in the ground for a rise in value or for future use.

The boomer, the promoter of fake oil and gas companies, the tales of coal-oil Johnnies, the space-writers for the magazines have the general public very much misinformed as to the actual conditions surrounding the production and marketing of natural gas.

But the statements of those who are in such positions that

[68] See *Oil and Gas Journal*, Nov. 30, 1911, p. 4.

they ought to know the fundamental facts of the natural-gas business unquestionably do the most harm. Let me quote a few gems of the kind, false though they be; they occur where only the real article is expected to appear.

The president of [69] a gas association said, in an address in 1906, of natural gas as follows:

"I believe by its judicious application and husbanding we will have *an everlasting supply* of this greatest of all fuels."

The director [70] of a State geological survey said before a gas association in 1910:

"We are trying to keep our gas at home. We need it. It is true, we have been wasting it about as fast as we could, but at the same time we don't want you all to take any of it away. What we do want is for you to locate factories here that will utilize our fuel. *We have plenty and to spare.* If the gas fields are ever exhausted, we have a few billion tons of coal to fall back on."

The most casual perusal of the publications of the United States Geological Survey would show that an "everlasting supply" is not to be expected, and that no field has "plenty and to spare." In contrast to these statements I quote from the Preface of the Geological Survey of Ohio, 1890, as follows:

"The natural-gas interests of the State have demanded and received in this report a measure of attention that is out of proportion to their intrinsic value. These interests are in marked contrast with the oil interests of the new fields in this respect, *viz.*, that, while the latter are almost exclusively in the hands of those whose knowledge has been derived from a varied and costly experience in the business, the former have been in many instances turned over to persons who have never seen a gas field aside from the particular one of which they are called upon to take charge. It is not surprising, under such circumstances, that crude and erroneous views in regard to the nature of the gas supply should find place among these companies and municipal boards, nor that a wasteful and extravagant policy in the use of the gas should be established or allowed by them. To convince such officials that gas is not being generated in the

[69] Proc. Nat. Gas Assoc. of Am., vol. i, p. 21.

[70] Same, vol. ii, p. 125.

underlying rocks as fast as their wells are able to withdraw it—that is, strictly stored power—and that every foot taken from the reservoir leaves the amount remaining there so much the less, has been a difficult, and in some respects a thankless, task. Nature has, however, become the teacher of all these communities that have broken into her storehouses of force, and falling pressure and supply-pipes half filled have come even more speedily than was expected to convince all who are able to learn that high-pressure gas fields are always exhausted by use, and that, in fact, they begin to die the moment they begin to live."

It is strange how persistent the idea is that oil and gas are being generated in the underlying rocks as fast as wells are able to withdraw them.

I once had the Governor of a great State tell me that oil in a certain field "was being formed right now" in such quantities that the "gushers would never give out," and that scientists had so informed him.

When a great oil gusher is tapped by the drill, even when in a wilderness far from any working pool or field, every effort is made to save this fluid.

The wildcat discoverer, although he may have been "hard up" financially, with no credit at the banks or supply houses the day before, immediately has plenty of credit. The tank builder rushes in tankage; the pipe-line companies rush in miles of pipe lines as the oil is wanted, and for cash as soon as it is in the tank.

When a wildcat well comes in a great gasser away in advance of regular development it is practically a dry hole and loss, so far as the discoverer's immediate finances are concerned, and the driller may wait months before he can get even the first cost of the well back.

Naturally the driller and oil-producer will not be careful of the gas when there is no money in it for them.

The general attitude of municipalities is well shown by the action of the city authorities at Findlay, Ohio.

The Tippecanoe well was drilled in about the close of 1888, some two years after the Findlay field was opened.

The well was located 2½ miles from the court house, on a town lot. To increase the flow the well was torpedoed, and

the first 24 hours after the well was shot it made better than 30,000,000 cubic feet.

The well was offered to the gas trustees of the city for $10,000. Instead of purchasing the well when they were short of gas and relieving the situation at once, they purchased an adjoining lot and proceeded to drill a well about sixty feet from the big gasser, expecting to get into the gas at the cost of drilling. Nature had unwittingly provided a tight place in the rock, and they got no gas, and the city's well was a complete failure even after being heavily shot. (See Geological Survey of Ohio, 1890, p. 117.)

Personally I have come across as mean and short-sighted actions as these in other places, much to the loss of the cities and discredit of the local authorities concerned.

Against the improper[71] use and wanton waste of natural gas many have made earnest but unavailing protest, receiving often the curses instead of the thanks of those in whose interests they have labored. To convince the most intelligent and fair-minded members of a community of the justice and wisdom of such views is an easy task, but, unfortunately, people of this kind are in a hopeless minority.

The highest and really the only proper use of natural gas is household use. In this field it meets the supreme test of doing the greatest good to the greatest number. If the world were wise and if genuine good-will controlled the actions of all, every foot of natural gas would be scrupulously saved for this service, but the world is not wise and universal benevolence does not bear sway.

As a practical matter the franchise rates for domestic consumption of natural gas should be much higher. Manufactured gas is sold at $1 per thousand cubic feet in many cities and successfully competes with coal and wood for domestic cooking and lighting.

Why should municipal authorities expect to get a better article for thirty cents or less and bring about conditions that tend to its waste and improper use when a higher price, say fifty cents, would prolong the use of the better article and thus eventually save their citizens a much larger sum than using

[71] See Dr. Orton, Bulletin of Geol. Soc. of Am., vol. 10, p. 106.

twenty-five-cent-gas a short time? Why howl about conservation and try to force people to furnish an article at less than a fair cost when such authorities have the means to bring about practical conservation and give their citizens the comforts of natural gas for a long period of time and at a less total cost than to force cheap natural gas for a short time, and then get to manufactured gas at treble the price?

If the distributing companies get a remunerative price so that they can make natural gas worth a cash price at the well so that there will be a profit to the well owner, in saving gas conservation of natural gas will automatically take place, as well as greater stability to the business.

Metallic Iridium. ANON. (*The Brass World,* viii, ix, 306.)—Iridium is extensively used for the points of gold pens, and is made from the powder obtained in the wet way from platinum ores by heating to a high temperature in a sand crucible and then adding stick phosphorus. The iridium is thus fused as an iridium phosphide. To remove the phosphorus, the phosphide is heated with lime, and metallic iridium is left as a hard white mass, so hard that it cannot be filed or cut and is broken up into small pieces to solder to the points of gold pens. These small pieces are ground to the right size on a copper disc wheel with emery or carborundum. It is stated that an ounce of iridium will make about 5,000 to 10,000 pen points. Iridium, thus prepared, is practically as hard as the ruby, and is the hardening agent in the so-called hard platinum.

A Cartridge Factory for Abyssinia. DAILY CONSULAR REPORT. (*Brass World,* viii, 9, 316.)—As other Powers have prevented the importation of arms and ammunition into Abyssinia, the Abyssinian Government has erected a cartridge factory in the capital, Adis Ababa. The cartridge manufacturing plant has been purchased in Germany and has a capacity of 10,000,000 cartridges per annum. The building is completed and the machinery has been shipped from Germany and will shortly arrive at Adis Ababa. There will be a workshop attached to the factory, in which 15,000 to 20,000 rifles can be repaired each year. The mechanics have been engaged in England and are on their way out to Adis Ababa. Power will be supplied to this factory, and to others in the capital, by a hydro-electric plant supplied by a Manchester firm. This plant is already erected at the power station on the river Akaki, 18 miles from the capital. It consists of two 200 horse-power dynamos, which will transmit 6000 volts to Adis Ababa, to be used both for power and street lighting.

THE PRODUCTION OF AVAILABLE POTASH FROM THE NATURAL SILICITES.[1]

BY

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THE great demand which has recently arisen for an American supply of potash in available form for agriculture has stimulated not only the search for new sources of this material but also experiments on a large and practical scale of operation, in the attempt to develop a method of making the vast supply of potash locked up in feldspars and feldspathic rocks either directly water-soluble or sufficiently soluble in dilute acids to insure a product which shall be useful as a fertilizer. The natural silicites commercially available as sources of potash are chiefly orthoclase and leucite. Both of these minerals are potassium-aluminum silicates. The theoretical formula for orthoclase is written $K_2O.Al_2O_3.6SiO_2$, and for leucite $K_2O.Al_2O_3.4SiO_2$. The principal sodium feldspar albite has the theoretical formula: $Na_2O.Al_2O_3.6SiO_2$. It is well known that these feldspars run into and substitute each other in various proportions, so that the products from different quarries will vary widely in respect to their soda and potash contents. There is an enormous supply of feldspar in the United States, both East and West, which could be made economically possible as a source of potash supply, provided the cost of production can be made low enough to compete with the potash-holding manure salts which are at present so largely imported from Germany. Although it must be admitted that the imported potash salts are richer in potash than any product that can ever be made from American feldspars, it should also be remembered that the crude German manure salts contain large quantities of chloride and sulphates of elements which are not only undesirable in the fertilizer but which may do actual harm under certain conditions. It is this fact which gives encouragement to the attempt

[1] Presented at the Eighth International Congress of Applied Chemistry, New York, 1912, and reprinted by permission of the authors.

to produce from American feldspars a straight potash fertilizer which could be used in exactly the same way that hardwood ashes have been found useful.

Six general methods have been proposed for decomposing the natural silicates, in the effort to obtain water-soluble potash salts.

I. ADAPTATION OF NATURAL AGENCIES.

In the processes of Nature, the slow action of moisture and atmospheric agencies, including the action of carbonic acid gas, is known to have a decomposing or kaolinizing action upon the feldspars. Immense deposits of feldspar and granitic rocks have thus been decomposed, with the formation of large beds of kaolin and clays from which the potash has been leached into the surrounding valley. For this reason, the valleys between feldspathic and granitic hills are usually highly productive of the crops which require large amounts of potash, such as tobacco, potatoes, large fruits, berries, etc. There have been a few processes proposed, which depend principally upon the natural reactions hastened by pressure and other agencies. In 1904 Blackmore (U. S. patent 772,206) proposed the action of carbon dioxide gas under five hundred pounds pressure upon a cream of the ground mineral, repeated intermittently for several hours, in the attempt to produce a yield of carbonate of potash. Ten years earlier the same experimenter (U. S. patent 513,001) had proposed using lime, calcium chloride, and steam pressure in an autoclave to produce chloride. In 1910 Coates (U. S. patent 947,795) proposed the addition of bacteria for the decomposition of feldspar. In 1910 Carpenter (U. S. patent 959,841) proposed to heat the mineral intensely and cool suddenly by plunging in water, in the effort to render the feldspar amorphous, in the hope of making it more available for plant growth. None of the above processes have as yet been shown to possess industrial possibilities.

II. WET PROCESSES OF A CHEMICAL NATURE.

Levi, in 1904 (French patent 344,246 and English patent 13,875), and Piva, in 1905 (French patent 351,338), proposed methods for treating leucite by means of solutions of alkali or alkali earth hydrates, generally under increased pressure. The

same general method for treating feldspar was claimed by Swayze in 1907 (U. S. patent 862,676) and by Gibbs in 1909 (U. S. patent 910,662).

Also, Gibbs, in 1904 (U. S. patents 772,612 and 772,657), proposed a process of treatment with hydrofluosilicic acid, and subsequently with sulphuric acid, in order to produce potassium sulphate. In 1907 Cushman was granted U. S. patent 851,922, a public patent which proposed the sludging of finely-ground feldspar with water, the addition of a small amount of hydrofluoric acid, and electrolyzing the mixture in wooden cells provided with wooden diaphragms. Under this process both potassium and aluminum hydrate passed through the cell diaphragm into the cathode compartment. This process, although perfectly practical, has not yet been made commercially possible, owing to the high cost of hydrofluoric acid and the large amount of by-products formed in the process. None of the above processes have as yet been made commercial possibilities.

III. DRY PROCESSES OF A CHEMICAL NATURE, IN WHICH THE POTASH SALTS ARE VOLATILIZED.

In processes of this nature, fluxes, and in some cases fuel, for reducing purposes are ground and mixed with the feldspar, the mixture being subsequently heated until the potash salts are volatilized and collected either in the stack dust or partially collected from the gases by passing them through or over water. Swayze, in 1905 (U. S. patent 789,074), heated ground feldspar with gypsum and carbon, and proposed to collect the volatilized sulphate. Spencer and Eckel, in 1909 (U. S. patent 912,266), made a cement mixed with calcareous and silicious fluxes and green sand, a natural potash-bearing iron silicate, clinkered the mixture in a rotary cement furnace, and obtained a Portland cement, at the same time collecting the potash in the stack dust and the flue gases. In 1911 Eckel (U. S. patent 1,011,172) proposed a somewhat similar method, but heated only high enough to drive off the potash salts and not high enough to clinker the mixture. Again, in 1911, Eckel (U. S. patent 1,011,173) melted a mixture of green sand, limestone, and fuel, tapped off the melted iron and slag, and recovered the potash salts from the flue gases.

Some of the processes under this heading have been tried

on a large scale. No great difficulty is recorded in driving off the potash in the furnaces, but obstacles were encountered in the attempt to collect the potash from the gases. As a by-product operation in the manufacture of cements, these processes may yet come to be of some industrial importance.

IV. DRY PROCESSES WHICH PROPOSE TO SEPARATE POTASH AS HYDROXIDE OR CARBONATE.

The old method of Bickell, proposed in 1856 (U. S. patent 16,111), which depended upon heating a mixture of feldspar, lime, and natural phosphate rock or guano to a bright red heat, has not as yet been proved practical or successful. The process of the Soc. Romana Solfati, in 1905 (French patent 352,275), which proposes the roasting of leucite with carbonate, hydrate, or nitrate of soda and lime, and subsequently the passage of steam through the roasted product to produce sodium aluminate and potassium carbonate, is possible from a chemical stand-point, but the high cost of operation has not permitted the process to come into commercial use.

V. DRY PROCESSES PRODUCING THE CHLORIDE.

These processes have been most experimented with upon the mill scale of operation.

In 1900 Rhodin (U. S. patent 641,406) and in 1901 (*J. Soc. Chem. Indus.*, xx, 439) proposed fritting feldspar with lime and salt. According to the published results, this experimenter obtained good yields, although the process has not become a commercial success. In 1907 McKee (U. S. patent 869,011) suggested heating a potash-bearing material containing mica with lime, salt, and carbon in order to obtain a yield of potassium chloride. Cushman, in 1911 (U. S. patent 987,436), proposed mixing feldspar with lime and salts of a mineral acid capable of decomposing the silicate, giving the mixture special treatment previous to heating in a rotary furnace in order to produce the chloride. This method has been tried out on a large mill scale of operation, and the results obtained will be discussed later on in this paper.

VI. DRY PROCESSES PRODUCING SULPHATES.

In 1911 Thompson (U. S. patent 995,105) proposed heating to a bright red heat mixture of feldspar, sodium acid sulphate, and sodium chloride, and subsequently leaching out the potassium sulphate produced. This experimenter claims that potassium chloride is first formed, which is subsequently changed to the sulphate by the action of the acid sulphate. It is stated that this process has recently been tried on a commercial scale of operation. Sodium acid sulphate is a by-product that is reasonably cheap, although a large quantity is not available. The lack of an abundant supply of acid sulphite is perhaps the greatest drawback to the commercializing on a large scale of this process, although it is possible that it may still become of some industrial importance. Hart, in 1911 (U. S. patent 997,671), proposed to fuse feldspar with some barium compound, such as the sulphate, together with carbon, to pulverize the cool melt, and subsequently to digest the product with sulphuric acid and thus produce in solution potash alum and a residue of barium sulphate and silica which is claimed to be useful as a paint pigment. Hart claims that some of the potash is volatilized during fusion. Since the fusion temperature is 1500° C., it is probable that a considerable portion of the potash does volatilize, and it is possible that this difficulty may interfere with the commercial success of the process.

Wadman, in 1907 (U. S. patent 847,856), proposed heating lepidolite with potassium sulphate and leaching the product with sulphuric acid in order to obtain sulphates of lithium and potash.

A chronological list of the patents which have been granted for the treatment of the silicates for the production of available potash is given in Table I.

It would appear that the most promising processes for making potash available from the natural silicates on a commercial scale of operation are those which are conducted in the dry way but without actual fusion of the reacting mixture. Potash salts volatilize readily at the high temperatures necessary for the fusion of the silicates, and the collection of the volatilized potash from the stack gases has not yet been carried out economically. A considerable portion of the potash does not settle in the dust

chamber, and if water sprays are used for washing the gases the potash solutions are very dilute and the cost of evaporation becomes prohibitive. Furthermore, water sprays are found to interfere with the draft regulation, even when the use of fans is resorted to. The maintenance of artificial draft is an expensive

TABLE I.

PROPOSED EXTRACTION PROCESSES CHRONOLOGICALLY ARRANGED.

	Patentee.	Year.	Process.	Product.
IV	Bickell	1856	Lime, $Ca_3(PO_4)_2$ red heat	Caustic.
I	Blackmore	1894	Lime, powdered $CaCl_2$, H_2O, steam	KCl.
V	Rhodin	1900	Lime, salt, heat under melting	KCl.
II	Levi (leucite)	1904	$Ca(OH)_2$ or NaOH, pressure 16 atmospheres.	K silicate.
II	Gibbs	1904	H_2SiF_6 and H_2SO_4	K_2SO_4.
I	Blackmore	1904	CO_2 500 pounds pressure repeating	K_2CO_3.
II	Piva	1905	(Leucite) KOH, NaOH, steam 25 atmospheres.	K silicate. K aluminate
IV	Soc. Romana Solfati	1905	(Leucite) alkali, carbon, CaO red heat.	K_2CO_3.
III	Swayze	1905	Gypsum and carbon, fuse, volatilize.	K_2SO_4.
VI	Wadman	1907	Lepidolite, K_2SO_4 H_2SO_4	K_2SO_4.
II	Cushman	1907	Water and HFl electrolysis	KOH.
II	Swayze	1907	Heat alone, then KOH solution	K silicate. K aluminate
V	McKee	1907	"Containing mica" with CaO, NaCl, and C.	KCl.
II	Gibbs	1909	$Ca(OH)_2$, steam 150 pounds	KOH.
III	Spencer and Eckel	1909	Green sand cement, mix, volatilize.	K salts.
I	Coates	1910	Bacterial action.	
I	Carpenter	1910	Intense heat, sudden cooling alone	
V	Cushman	1911	CaO, $CaCl_2$, etc., clumps, red heat	KCl.
VI	Thompson	1911	$NaHSO_4$, NaCl, bright red	K_2SO_4.
VI	Hart	1911	Ba compound as $BaSO_4$ and C, fuse, H_2SO_4.	Alum.
III	Eckel	1911	Cement mix but not over 900° C. with green sand volatilize.	K_2O. K_2SO_4.
III	Eckel	1911	Green sand, $CaCO_3$ and C. melt iron volatilize.	K_2SO_4.

and difficult matter, and is very likely to interfere with the proper control of the furnace temperatures. For work on the large scale of mill operation, a continuous process must be used, avoiding fusion and with the regulation of temperature to the exact point at which appreciable quantities of potash do not volatilize. The fluxes and reacting substances must be cheap, available in large quantity, and the yields of water-soluble potash salts must be

high. The process which has seemed to us to give the most promise of successful adaptation to commercial ends is that of Cushman (U. S. patent 987,436), coupled with the method of preparation of the materials before furnacing, proposed and developed by Coggeshall (U. S. patent 987,554).

This process has recently been given extensive trials on a large scale and interesting results have been obtained. The process consists essentially in powdering 100 parts of potash feldspar rock, together with about 20 parts of lime and with or without 10 to 20 parts of rock salt. This powdered mixture is fed to the top of a moving drum about three feet in diameter, in a layer about half an inch deep. As soon as the layer is formed a strong solution of calcium chloride is applied from a series of small tubes. The $CaCl_2$ at once unites with the lime, forming a so-called oxychloride cement, and a large portion of the mixed powder is thereby at once formed into "clumps" or aggregates lying in a bed of surplus powder. As the drum revolves the bed is removed by a scraper to a belt which delivers the mixture to a screen which separates the clumps from the residual powder. The powder is returned by a screw conveyor and elevator to the hopper above the drum again. The clumps are about the size of peas and pass from the screen directly to a rotary kiln similar to those used in burning Portland cement. The kiln is heated by a blast of air and powdered coal in the usual manner.

The clumps pass regularly down through the increasingly heated portions of the rotating kiln and roll out at the end, practically without alteration in size and shape.

A large percentage of the total potash present in the feldspar is converted into potassium chloride during the heat treatment, and very little is volatilized. The dry clumps are of a pale-yellow color outside, due to the iron in the ash of the bituminous coal used, but they are snow-white inside. The clumps are finally ground, producing a pale-yellow material containing as much water-soluble K_2O as hardwood ashes, although the potash is in the form of chloride and the product also contains considerable free lime. Up to the present time no attempt has been made on a large scale to leach out the soluble potash. The ground material is being given field tests as a straight potash fertilizer containing lime.

A RÉSUMÉ OF THE LARGE SCALE EXPERIMENTS.

Potash feldspars were obtained from five different localities. Eleven carloads were used in the trials, amounting to a total of 385 tons. Each carload was ground and analyzed separately. The lowest in potash ran 6 per cent. K_2O and 3 per cent. Na_2O, the highest 11.3 per cent. K_2O and 3.1 per cent. Na_2O; the bulk of the spar 10 per cent. potash and 2 per cent. soda, and the results given in this paper were obtained on the 10 per cent. spar.

The lime was a high calcium quick-lime, running about 90 per cent. CaO and 5.6 per cent. MgO.

The salt was rock salt from New York State and ran about 98 per cent. NaCl.

The calcium chloride was obtained from the Solvay Process Company. It was in the solid form and contained about 75 per cent. $CaCl_2$ and 25 per cent. water.

All of the above materials are available in very large quantities and at low cost. The calcium chloride is a by-product in the form of a moderately strong solution, and but a small proportion is concentrated at the present time, as the chief use is for refrigeration purposes. Vast quantities are now run to waste. The solid form was used in these trials merely for convenience.

Many heats were made with mixtures of varying proportions, but the two mixtures used in the work here described were:

Feldspar	100	Feldspar	100
Lime	20	Lime	20
Salt	10	Salt	20

The feldspar, lime, and salt were separately crushed in gyratory crushers and rolls, and dried in a rotary drier. In continuous work the proper mixture would be made at this point by continuous weighing machines, but as a number of different mixtures were to be tried, each of the three raw materials was ground separately in Huntington mills and put into bins. This preliminary grinding of the feldspar and salt was to about 65 per cent. through a 100-mesh sieve, of the lime about 83 per cent. through the 100-mesh. The weight per cubic foot of each powder of the above fineness was then ascertained, and measuring boxes were built so that the materials could be separately measured out and run together into a large mixing machine. Almost

a ton was thus mixed each time. The mixture was then conveyed to a tube-mill and further ground to a fineness of from 97 per cent. to 99.5 per cent. through a 100-mesh sieve, and then conveyed to the bin over the clumper and kiln.

The calcium chloride masses were broken up and thrown on a perforated grid in a large tank holding about 48 tons. Water was run in and the chloride dissolved most readily. The solution was run out when about 42° Beaumé into two large sump tanks, and brought to a constant strength of about 42 per cent. $CaCl_2$. This was then pumped up to an elevated tank and piped from there through a constant-level tank to the dropper tubes of the clumper placed in a row above the drum. This drum is 15.5 feet long and 3 feet in diameter, and is horizontal. There are 15 valved pipes, each one feeding an adjustable pipe holding 38 short dropping tubes of brass 1/16 inch internal diameter and set 5/16 inch apart.

The finely-ground, mixed powder is taken from the bin by a chute, elevator, and screw conveyor and distributed in a long hopper trough over the drum. It is taken from the trough by a roll device and spread evenly on the moving drum at its topmost point. The drum has a surface velocity of about 1.6 inches per second, the layer of powder advancing at this rate.

It was found that by dropping the liquid very rapidly upon the powder the clumps could be made rapidly enough to give a full feed to the short rotary kiln when only one-third of the trough and droppers and drum is used. A clumper drum 5 feet long produces every hour almost two tons of fresh clumps and considerably over a ton and a half of burned product with the kiln used in these trials. The excess of powder passes through a screen and goes to the same elevator which lifts the original material from the bin. The amount of actual $CaCl_2$ in the fresh lime is regulated to about 20 parts to each 100 parts of feldspar in the mixture. The clumps leave the screen in rounded form and flow directly into the kiln.

The reason for the above procedure will now be explained. In the first place, calcium chloride reacts very efficiently under these conditions with the feldspar by replacing the potassium with calcium, thus forming calcium silicate and potassium chloride. Anhydrous calcium chloride is expensive to produce, and it is impracticable to grind it into a mixture on a large scale on

account of the rapid absorption of moisture. Even if such a dry mixture could easily be made, its use would present certain disadvantages.

When a reaction between an ore and solid fluxes is produced by heating up to the fusing temperature, the reaction takes place on the surface of the particles alone and only at the points where the ore is in actual contact with the flux particles. Finer grinding will produce a larger surface area and thus a greater number of actual contact points, leading to a larger yield. There is, however, a degree of fineness beyond which it is not wise to go, on account of the cost of extremely fine grinding.

Another factor in the problem is brought out by the following experiments. A batch of ore and the theoretical amount of solid flux were ground together to just pass a 50-mesh sieve. This powder, when subjected to a certain heat treatment, gave a reaction yield of about 35 per cent. of the theoretical. The mixture was then ground to just pass a 100-mesh sieve and given the same heat treatment. A reaction yield was obtained of about 65 per cent. of the theoretical. The mixture was then ground to pass a 200-mesh sieve and again reheated as before. A smaller yield was obtained than when the material just passed the 100-mesh, although the particles were undoubtedly only half the average diameter with about four times the surface area and should therefore have had far more points of contact. Upon weighing equal volumes of the 50-mesh, 100-mesh, and 200-mesh powders, it was found that the latter contained far less material, and it became apparent that the 200-mesh powder consisted for over 54 per cent. of its volume simply of voids. Such finely-ground powders are well known to "surge"—that is, to show the tendency to flow like water through orifices in a manner resembling fountains. Material ground as fine as this is the cause of much trouble at spout slides and conveyors. Each particle of a material of this extreme fineness is undoubtedly surrounded by a film of air, the actual contact with the surface is lessened and friction almost eliminated. When allowed to flow into a bin, such a powder assumes an almost horizontal surface; there is practically no angle of repose. Unquestionably the lessened contact caused the low yields in the finely-ground mixtures. Some of the finer material was briquetted and the subsequent heat yield about 85 per cent. of the theoretical. Briquetting is,

however, expensive and usually necessitates the addition of a binding agent foreign to the reaction.

As a result of these investigations, the method was developed for aggregating fine powders by dropping a suitable liquid upon an excess of the powder in such a way as to cause a temporary bond to form, thus practically eliminating the air films or voids around the individual particles and permitting actual surface contact. Under these conditions, with the same ore and flux used in the experiments described above, the same heat treatment yielded within 3 per cent. of the theoretical quantity present. This method of aggregating finely-powdered materials previous to furnacing has already been used in several different ways. For example, in an ore mixture in which the fluxing material is an alkaline carbonate, such as sodium or potassium, which forms crystalline salts containing water of crystallization, if the carbonate is used in the partially anhydrous condition and ground with the ore water alone dropped upon the mix in the manner described formed at once a crystalline carbonate which binds the particles of ore and flux into separate clumps, which are hard enough to withstand screening, while the air films are practically eliminated. Using such a mixture and process as this, a practically theoretical yield was obtained, although the flux was used only in the exact molecular proportion called for by the reaction.

By this clumping process a very intimate contact of reaction of surfaces is readily obtained at a low cost. The quantity of flux necessary to complete the reaction is greatly reduced, the duration and temperature of the heat treatment is lessened, and, working with rotary kilns, dusting and stack losses are almost entirely eliminated. The clumps are beautifully adapted to the feed mechanism of rotary kilns, as they flow easily, do not dust, and take the heat more evenly than fine powders. Now that the temperature conditions in rotary kilns can be accurately controlled, it would seem that many chemical and metallurgical reactions which are now performed by intermittent processes and with low yields could be much more economically carried out in continuous rotary kilns, taking advantage of this new method of forming aggregates previous to furnacing.

In the application of this method to the treatment of feldspathic rock, advantage was taken of the fact that a solution of calcium chloride acts upon dehydrated lime to form the oxy-

chloride, which is a strong cementing compound. It was found that the formation of calcium oxychloride gave a sufficiently strong bond to enable the aggregates to withstand the operation of screening and the burden in the kiln.

The theoretical quantity of calcium chloride flux required depends upon the total quantity of K_2O and Na_2O present in the mix, as it is evident that the soda must also be liberated in proportion to its content. The feldspar ore used ran 10 per cent. K_2O and 2 per cent. Na_2O, which required theoretically 15.5 parts of calcic chloride. In all our trials some slight excess of calcium chloride has been used. The strength of the solution and the method of treatment have been such that about 20 parts of actual calcium chloride are present in the fresh clumps to every 100 parts of feldspar. The 20 parts of lime used are for the purpose of forming the aggregates, and this lime remains practically unchanged in the finished product. The presence of lime in a potash fertilizer will be found advantageous to most soils, and it is generally admitted that lime increases the manurial value of a fertilizer. If the object was to leach out the soluble potash salts from the product, a much smaller amount of lime could be used without interfering with the formation of hard clumps. The salt is added because it has been found to aid the heat reaction, probably mechanically, as will be explained later on. The fresh clumps contain from 16 to 20 per cent. of moisture, which is, of course, evaporated in the upper part of the kiln.

The rotary kiln used in these trials was one of the old bottle shape cement kilns with a total length of slightly over fifty-five feet, the upper twenty feet having a diameter of 4 feet clear inside the firebrick lining, the lower portion widening out to nearly 6 feet inside diameter. The pitch was ⅞ inch per foot, and the most suitable speed was found to be one revolution in about 2½ minutes.

The conditions of the heat treatment are very important. The kiln used was too short to yield the best results, and after the preliminary experiments changes were made which caused the material to take about 1½ hours to pass through the length of the kiln. The temperature of the gases issuing from the upper end of the kiln were read continually with a thermo-couple pyrometer fitted with a 15-foot fire end, and temperatures were also taken from time to time at the firing platform. A furnace

wall temperature of about 1370° C. is required for efficient burning of powdered bituminous coal. This is, however, much too high a temperature for potash work in a rotary kiln. This difficulty called for careful experimental investigations and adjustments of the heat treatment before the proper yields could be obtained. If a longer kiln had been available, there is every reason to believe that a more efficient use of the heat could have been obtained. The coal used was a fairly high volatile bituminous coal. It was ground to about 94 per cent. through a 100-mesh sieve and blown into the furnace under an air pressure of about ten pounds per square inch.

During the progress of the clumps down the kiln the following reactions probably take place: At the entrance to the kiln the water begins to evaporate. As the hotter zone is approached, the temperature rises high enough to melt calcium chloride and salt. Whether the calcium chloride is free to melt is not known to us, as the exact composition of the oxychloride compound formed has not yet been determined. The results of our work seem to prove that the reacting chlorine is more readily evolved from the oxychloride compound than it is from calcium chloride alone. The melting of the salt, however, continues the bond of the reacting particles, causing them to thoroughly "wet" each other, and from this point on the attack on the silicate proceeds rapidly. During the heating usually from 1 to 2 per cent. of Na_2O is volatilized.

When operating with no salt present, the yield of soluble potassium chloride was 47.5 per cent. of that originally present in the feldspar. On adding to the mixture 10 parts of salt to each 100 of spar, a test heat yielded 64 per cent., but of this 9 per cent. was lost by volatilization, giving a yield of 55 per cent. net in the final product. On adding 20 parts of salt to the mixture the yield grows to 69.2 per cent. with no volatilization and to 75 per cent. under heat conditions which caused a volatilization of 7 per cent., leaving a net yield of 68 per cent. of that originally present. In the case of clumps made from a mixture of 100 parts of feldspar containing 10 per cent. K_2O and 2 per cent. Na_2O, 20 parts of lime, 20 parts of salt, and 20 parts of calcium chloride, the theoretical composition if no volatilization loss takes place is shown compared with the actual results obtained in the following table:

	Theory.	Analysis.	
Total K_2O	6.25%	5.8%	
Water-soluble K_2O		4.2%	Equals 6.65% KCl.
Loss of K_2O		.5%	As KCl already formed.
Total Na_2O	7.62%	7.1%	52% made into NaCl.
Water-soluble Na_2O	6.37%	5.1%	Showing 1.79% vaporized as NaCl or 26% of that present.

This particular product contained 11.2 per cent. of free lime, and total lime by analysis 15.5 per cent. There was also in this sample about 5 per cent. of free unchanged calcic chloride. The amount of calcic chloride in the various runs made up to the present time has been reduced gradually to about 1 per cent., and it is felt that in the future better conditions of heat treatment will make complete use of the calcic chloride and at the same time raise the yields of soluble potash. In later runs, in which only 10 parts of salt were present in the mix, the theoretical and actual analysis of the product was as follows:

	Theory.	Analysis.	
Total K_2O	6.66%	5.62%	
Water-soluble K_2O		4.5 %	Equals 7.12% KCl.
Vaporization loss of soluble K_2O		1.04%	As KCl already formed.
K_2O insoluble in water		1.12%	
Total Na_2O	4.15%		
Water-soluble Na_2O		3.7 %	Showing 0.45% vaporized as NaCl or 11% of that present.

This product contained 12.25 per cent. of free lime, the total potash rendered soluble was 5.54 per cent. of the product or 83.2 per cent. of the total quantity present, but as 15.6 per cent. had been volatilized the net yield in the product amounted to 57.6 per cent.

The material which was later made continuously according to the process described above carries 4.5 per cent. of water-soluble K_2O in the form of 7.12 per cent. potassium chloride, and in addition to this material carries only 1.12 per cent. K_2O insoluble in water. It is well known that a 2 per cent. citric acid solution will extract, when used according to the Wagner method, somewhat more K_2O than can be made directly water-soluble. This fact is of considerable interest when the product is to be used directly as a potash fertilizer.

CONCLUSION.

It is believed that under better conditions of heat treatment which can be obtained with longer kilns and with a somewhat different arrangement of the combustion chamber, slightly better yields than those reported can be obtained. It should be remembered that the kiln used in these experimental trials was originally designed for burning cement, but this type of kiln has long been superseded by improved forms. In order to get the proper heat treatment in the middle of the kiln to complete the reaction, it was necessary to have the upper part too hot. This condition will not maintain in a properly-designed kiln. It is also believed that the use of oil as fuel would have allowed an easier regulation of the heat treatment, but the trials so far undertaken have been made under conditions which were found available at the time.

The subject of the costs of this process and of the product cannot be gone into in detail at this time, but a few general statements may be made. The production of water-soluble potash in feldspathic rock is essentially a low-grade proposition, and the commercial success of such a process depends upon the low cost of the various operations. The manufacture of a straight potash fertilizer containing as valuable ingredients only potash and lime must be carried out on a very large scale and by the most modern methods of continuous operation. With regard to the clumping process, the trials have shown that this operation can be practically carried out as a continuous process and at an exceedingly low charge per ton of product.

The process may be directly compared with that of the manufacture of Portland cement. It is a little easier to grind feldspar and lime than the shales and limestones used in cement manufacture. Drying will cost no more. Chemical control of the raw mixes will not be more expensive, and perhaps much less. Clumping, as has been shown, adds a very small charge to the expense of treatment. The cost of furnacing the feldspar mix will be less than similar charges in the cement industry, as the temperatures required are much lower and less coal is consumed. The product from the potash kiln is comparatively soft and pulverizes easily in hammer mills, while the charges on the cement industry for grinding clinker are an important item. Again, the

softer potash product merely requires to be ground fine enough for use as a fertilizer, whereas cement clinker must be ground very fine and costs rise rapidly with increasing fineness. Repair bills in the case of feldspar treatment should be much smaller than in cement manufacture. The charge for raw materials is somewhat larger than in the case of cement, but this is more than met by the smaller costs of operation.

The potash fertilizer as now produced should be the equal in fertilizing value of the ordinary grades of hardwood ashes. The product carries practically the same content of water-soluble potash and somewhat more lime than wood ashes. There is every reason to believe that if the process becomes an industry the yields of water-soluble potash can be considerably improved. The material yielded is not a fused product; it is friable as an ash, and it has the physical texture to make it a valuable aid to soil structure. The success of the product must, of course, depend upon the results obtained under test conditions in its experimental use as a fertilizer. If results are obtained which are as good as, or better than, those which usually attend the proper use of high-grade wood ashes, it is believed that there should be no reason why this product cannot be successfully produced and introduced, especially in those parts of the country where potash feldspars, fuel, and shipping facilities are available.

SUMMARY.

In this paper a summary is given of the various processes which have been proposed for making the potash in the natural silicates available as a fertilizer.

Experimental trials of a new rotary kiln process for treating feldspar are described, which depends upon a previous treatment before furnacing, consisting of a method of aggregating or clumping the mix so that chemical contact of the reacting substances is brought about during the subsequent processing. The qualitative and quantitative results obtained on a number of experimental trials on a mill scale of operation are presented and discussed. It is shown that it is possible to economically manufacture a potash fertilizer containing free lime from feldspar, and for a sufficiently low cost to make an industry based upon the method worthy of consideration.

A METHOD OF IMPROVING THE SENSITIVENESS OF THE TELEPHONE RECEIVER AS A DETECTOR IN ALTERNATING CURRENT NULL MEASUREMENTS.

BY

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THE numerous applications of the electrostatic condenser have lately directed attention to the necessity for a quick and accurate method of measuring the capacity of such condensers. It is generally recognized that condensers whose dielectrics are materials of low cost and of good mechanical working quality usually have electrical characteristics that seriously impair the accuracy and reliability of direct current measurements of their capacity. The presence of appreciable polarization, of residual effects, or of leakage, causes the apparent capacity as obtained by direct-current methods to be quite different from the true or Maxwellian capacity. It is true, in the case of standard condensers made from a good quality of mica, that there is substantial agreement between the results obtained by various methods; but even in this case there will always be differences, so that for the highest precision it is necessary to calibrate such condensers on circuits having characteristics similar to those of the circuits upon which the condensers are afterward to be operated.

It has been found that an alternating-current bridge measurement is most reliable in all cases, since the true capacity, unaffected by leakage, by polarization, or by dielectric loss, is directly determined. More exactly, the unknown capacity is found in terms of the known capacity of a standard or reference condenser. Moreover, since the capacity balance of the bridge cannot be obtained without a simultaneous phase balance, the same measurement affords knowledge of the phase angle of the tested condenser, and hence of the energy loss in the material comprising the dielectric. But the success of this method depends upon the detector used to indicate when the bridge is balanced. In comparing condensers of similar characteristics, for instance two good mica condensers, the ordinary high-resistance telephone receiver is quite serviceable when testing on circuits of frequency not

lower than 150 cycles per second; but the telephone receiver is extremely insensitive at commercial frequencies. Moreover, when commercial condensers are to be compared with reference condensers, which latter usually have a good grade of mica as dielectric, the exaggeration of any harmonics that may be present in the testing voltage wave, and the periodic shifting of phase of the poorer condenser, make it extremely difficult to secure a balance at the fundamental frequency, which cannot coincide with the point of balance for any one of the harmonics.

The ideal detector is, of course, the vibration galvanometer. Failing this, a mechanical rectifier with a direct-current galvanometer will give good results; but either of these devices requires for satisfactory operation a stand or table practically free from vibration. This can be secured, in more or less cumbersome ways, but the attention and expert manipulation required make these detectors suited primarily for use in the laboratory.

This paper is intended to describe a modification of the telephone detector, which the author has found extremely sensitive, and which does away with the difficulties and limitations ordinarily encountered in using the receiver as a detector. It is a fact that the human ear, although quite sensitive to a high-pitched musical tone when subjected to that tone only, becomes unable to detect the exact point of extinction of this tone when higher harmonics or overtones are present. But if another tone, slightly differing in pitch from the fundamental, be impressed at the same time, the ear will at once recognize the discord. This is true even when the discordant tones are both extremely faint; in fact, it seems to be evidenced that the most delicate sensibility prevails when this condition is realized. If, then, a steady, feeble tone of slightly different frequency from that of the testing voltage be impressed on the ear, the fact that the bridge is balanced will be indicated by the absence of "beats," although there may be still present quite audible tones due to various harmonics. This was accidentally noticed by the author during a bridge comparison of two mica condensers. An alternating-current arc lamp was being operated on the floor below, and the slight hum from the arc, coming to the ear through an opening in the floor, developed plainly audible beats when the bridge was slightly out of balance.

Several cheap and simple applications of this scheme are at once obvious. In a laboratory it will generally be found that a tuning-fork is at hand, whose frequency is but slightly different from that of the test circuit. It is best to choose a fork of higher frequency, and bring the latter down, by the addition of weights, to the required value. By arranging a very simple make-and-break contact on the fork, which may be hand- or electrically-driven, beats can be obtained by holding the test receiver to one ear, and holding to the other ear a second receiver in circuit with a single dry cell, a resistance of suitable value, and the tuning-fork make-and-break contact. The hands may be left free to manipulate the bridge, if operators' or head-type receivers are available.

In a commercial test, as carried out in a manufacturing plant, a small induction motor will generally be available. If this is of the squirrel-cage type, it may be arranged to drive a small alternator, the voltage from which will differ in frequency from that impressed on the motor sufficiently to be used in this way. If a wound type motor with slip rings is at hand, it may be driven at slow speed in any convenient way, when the voltage from the slip rings will have the desired slight difference of frequency from that impressed on the stator windings. It will be found that the ear is most sensitive to a discord giving from three to six beats per second.

The chief usefulness of this device is on circuits of frequency below 150 cycles per second; say on 25- or 60-cycle circuits, where the telephone receiver *per se* is quite useless as a detector. This method of beats will be found surprisingly sensitive; in fact, other things being equal, the sensitivity depends only upon the difference in frequency between the two tones, and it seems possible that frequencies above the audible limit may be available by the use of a modification of this method.

In conclusion, it may be said that but one obstacle presents itself to the use of this method in commercial testing; namely, the difficulty of securing a quiet place for the test. But a simple device which will secure an air-tight connection between the receiver and the outer ear will overcome this difficulty. The author has found that moistening the ear with a damp handkerchief will cause the receiver to make a sufficiently tight connection.

RECAPITULATION.

This paper describes a method of employing the watch-case telephone receiver in the comparing of capacities by the alternating-current bridge method. The use of this scheme does away with the difficulties ordinarily encountered in attempts to use the receiver in this way. The success of the method is due to the fact that the human ear is much more sensitive to a noise or sound of very low frequency, in the presence of a barely audible note of high frequency, than to the latter alone. By this method, which is here denominated the "method of beats," such a receiver may be used to balance an alternating-current capacity bridge:

(1) On frequencies too low to sensibly affect the ear.

(2) In cases where the time-constant balance is a function of the current strength in the bridge circuit.

Simple means are suggested for the ready application of the method to commercial as well as to laboratory measurements.

WILKINSBURG, PA., November 9, 1912.

Color of Brass. ANON. (*Brass World*, viii, 9, 330.)—The composition of brass may be approximately determined by its color.

Brass containing 5 per cent. zinc—red.
Brass containing 10 per cent. zinc—bronze color.
Brass containing 15 per cent. zinc—light orange.
Brass containing 20 per cent. zinc—greenish - yellow (green brass).
Brass containing 25 per cent. zinc—greenish - yellow (green brass).
Brass containing 30 per cent. zinc—true yellow brass color.
Brass containing 35 per cent. zinc—true yellow brass color.
Brass containing 40 per cent. zinc—reddish-yellow.
Brass containing 45 per cent. zinc—rich golden color (orange).
Brass containing 50 per cent. zinc—richer golden color.
Brass containing 55 per cent. zinc—like 14-karat gold.
Brass containing 60 per cent. zinc—yellowish-white.
Brass containing over 60 per cent. zinc—white and then gray.

Or, very soft brass, red or orange, contains 10 to 15 per cent. zinc, greenish-yellow brass contains 20 to 25 per cent. zinc, brass of the true brass color contains 30 to 38 per cent. zinc, and hard brass, of orange-yellow color, contains more than 38 per cent. zinc, and less than 60 per cent.

THE ESTIMATION OF PHENOL IN CRUDE CARBOLIC ACID AND TAR OILS.[1]

BY

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A PROBLEM which is occasionally presented to the chemist engaged in the examination of various tar products is the determination of actual phenol (C_6H_5OH) in the substance under consideration. Usually all that is required is the estimation of total phenols, generally called "tar acids." These tar acids consist of a complex mixture of phenol, cresol, and various higher homologues, and their quantitative estimation *in toto* is always based on their common chemical property of solubility in a solution of caustic alkali. Sometimes, however, it is necessary to proceed further, and ascertain how much of these tar acids is real phenol.

At present, so far as the writer has been able to learn, there is no satisfactory solution of this problem in the literature. Many tests for qualitative distinction of phenol, cresol, and the higher homologous oxygenated aromatic hydrocarbons have been proposed. Some of these are of very doubtful value, even qualitatively, but none are all susceptible of even approximate quantitative application.

The only real attempt in this field was that of Charles Lowe (see Lunge's Coal Tar and Ammonia, Fourth Ed., pp. 608–9). This is proposed for crude carbolic acid, and is more a specification for material than a method of analysis. Briefly, it consists in plain distillation in a retort, with no attempt at fractionation, and subsequent determination of the melting point of an arbitrary fraction. This fraction is a definite volume per cent. after removal of the water. The percentage of phenol is determined by adjusting a mixture of phenol and cresol (mixture of the three isomers) to have the same melting point. This is a method

[1] Communicated by the author. See also "Note on the Rideal-Walker Phenol Control," by J. T. A. Walker and J. M. Weiss, JOURNAL FRANKLIN INSTITUTE, 174, 101.

evidently only applicable when the percentage of phenol is large and when there is no disturbing influence of higher homologues.

The writer, in attacking this problem, decided that chemical properties would be inferior to physical properties as a means of distinction, in view of the fact that the material sought existed in mixture with bodies very closely related chemically to it. To separate phenol from all bodies except the next higher homologues, the cresols, is a comparatively simple task, and one which can be accomplished in a convenient and easy manner. Further, if the physical properties of a large number of varying mixtures of phenol and cresols are known, the estimation of the phenol is possible, the exactness varying with the number of such known mixtures. This really is the gist of the work undertaken by the writer, and the practical results of the investigation are presented in this paper.

The work was complicated by the fact that the three isomeric cresols exist with varying physical properties, and the possibilities of mixtures with four variables are enormous. This phase of the question, as will be seen later, was considerably simplified.

As a preface, it may be well to give the physical properties of phenol and the cresols, as taken from Van Nostrand's Chemical Annual:

	Melting point.	Boiling point.	Specific gravity.
Phenol	42.5°–43° C.	182.6°	1.0677
o Cresol	30°	191°	1.0511
m Cresol	3–4°	202°	1.0390
p Cresol	36°	202°	1.0390

The specific gravities are given for the cresols at 15°/15° and for phenol at 35°/35°. Beilstein gives the following figures:

	Melting point.	Boiling point.	Specific gravity at 0° C.
Phenol	42.5°–43° C.	178.5°–184.1°	1.0906
o Cresol	30°	190.8°	1.0578
m Cresol	3°	202.8°	1.0498
p Cresol	36°	201.8°	1.0522

As may be seen, the specific gravities and boiling points of *m* and *p* cresols are quite close together, and these two always occur together in commercial mixtures; therefore, to simplify

matters, a mixture of these was used instead of the pure separate materials, thereby reducing the variables to be considered to three. The *m* and *p* cresols cannot be separated by physical means, and to prepare them pure is a very extensive and difficult task. As to the accuracy of the above figures given by various authorities for the physical constants of these substances, the writer feels that in many cases they are inaccurate and will take up this phase of the subject later.

The phenol used was prepared synthetically from pure benzene, the *o* cresol by fractional extraction of a mixture of cresol, with caustic soda solution, subsequent crystallization from petroleum ether, and final fractional distillation. The mixture of *m* and *p* cresol was separated by a very careful and efficient fractionation of a fraction of but two or three gallons taken from a works still handling large charges. The tests of these materials are given below:

	Phenol.	*o* Cresol.	Mixture of *m* and *p* cresol.
Solidifying point	40.5° C.	27.75°	Below —10° C.
Specific gravity 25°/25°		1.0429	1.0313
Boiling point range ...	179° first drop	189° first drop	198° first drop
	180° 1%	190° 19%	199° 2%
	181° 92%	191° 93%	200° 6%
	182° 100%	192° 100%	201° 81%
			202° 100%

To obtain some idea of the purity of these substances, the effect of 5 per cent. of *o* cresol or the *m*–*p* cresol on the phenol boiling point was determined, as follows:

95% phenol, 5% *o* cresol.	95% phenol, 5% *m*–*p* cresol.
177° first drop	178° first drop
178° 2%	179° 7%
179° 4%	180° 10%
180° 9%	181° 23%
181° 88%	182° 85%
182° 96%	183° 93%
184° 100%	185° 97%
	190° 100%

Similarly, *o* cresol with 5 per cent. phenol addition had a range in boiling point of from 186° to 192° C. The method

for taking boiling-point range was a distillation of 100 c.c. in a Jena flask protected by an asbestos ring and connected to a 24-inch condenser. Naturally, there is a certain lag of the thermometer at the start and a slight superheating at the end which tends to enlarge the range, even of a pure substance. The presence of a trace of water, hard to avoid in such hygroscopic substances, also causes a slight amount of material to distil below its true boiling point. On the phenol, practically 90 per cent. boiled between 180° and 180.5°, and no fraction could be obtained having a higher solidifying point than 40.5° C., no matter how many times it was distilled. The same was true of the ortho-cresol on distillation—no fraction could be obtained with a solidifying point over 27¾° C. These solidifying points were taken on a large quantity of material with the thermometer in the liquid. The thermometer was a Jena glass normal thermometer that has been checked by the United States Bureau of Standards. The writer therefore considered his materials practically absolute, and deemed that the high figures given by earlier investigators as to melting point were inaccurate either because of erroneous thermometers or from the use of too small quantities of material.

A large number of mixtures were made with the above materials, using 0, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 95 per cent. phenol, and for each percentage of phenol eleven variations of the proportions of *o* and *m–p* cresols were used, making in all 132 mixtures. The boiling-point range, specific gravity, and solidifying point of all these mixtures were then determined.

For the purposes of this paper it is unnecessary to detail all the figures obtained on these mixtures, but only to give those which would be of practical value to the worker. It was found that for all but unusual cases the determinations of solidifying point and specific gravity were enough to characterize the mixtures as to their percentage of phenol, and that a determination of boiling-point range was superfluous.

The procedure for determining the percentage of phenol in a crude carbolic acid or a tar oil should be as follows: A definite volume of material should be taken, sufficient to give 300 c.c. of total phenols (tar acids). This should then be treated with

sufficient caustic soda solution to dissolve all tar acids. The solution of acids in soda is carefully separated from the neutral hydrocarbons and then steam-distilled until no oil is present in the distillate. This insures the removal of all material not tar acids. The soda solution is then cooled, brought into a separatory funnel, and acidified with 40° Baumé sulphuric acid. The mass is allowed to settle, and the lower layer of sodium sulphate discarded. The upper layer of phenols is brought into a distilling flask with a Hempel tube, and distilled up to 170° C. vapor temperature. This removes water, but a small amount of acid is carried over in the process. This latter is separated from the water and returned to the flask. The distillation is then continued, and two fractions taken off, the first up to 190° C. and the second from 190° C. to 202° C. This second fraction is redistilled, taking all up to 197° C., and is added to the 190° fraction obtained in the first distillation. This combined fraction contains all the phenol and none of the homologues above cresol, and is tested for solidifying point and specific gravity.

The solidifying point is taken on about 50 c.c. in a test-tube with the thermometer in the liquid and cooling until separation of crystals occurs. At this point there is a constant temperature for a short period which is taken as the solidifying point. If the material supercools, crystallization may be brought about by addition of a minute crystal of phenol: in this case the temperature rises as the crystals separate, and the highest point reached is taken as the solidifying point. The specific gravity should be taken on a Westphal balance at 25° C. and referred to water at the same temperature.

These figures are compared with those given below, the per cent. of phenol noted, and the result figured back to the original material. In considering these figures, it should be remembered that *o* cresol tends to simultaneously raise both the specific gravity and melting point of a mixture, and therefore up to a certain point with increase of melting point the gravities corresponding to the same percentage of phenol also increase.

Various mixtures which may occur as a result of the above procedure are given in a rough classification.

Solidifying point below 0° C.:

Specific gravity $\frac{25}{25}$.	Per cent. phenol.
up to 1.032	0
1.035	5
1.040	10
1.043	20
1.047	30
1.049	40

Mixtures above 40 per cent. phenol have a solidifying point over 0° C.

Solidifying point 0–5° C.:

Specific gravity $\frac{25}{25}$.	Per cent. phenol.
up to 1.038	0
1.040	5
1.042	10
1.045	20
1.048	30
1.052	40

Solidifying point 5–10° C.:

Specific gravity $\frac{25}{25}$	Per cent. phenol.
1.039	0
1.041	5
1.043	10
1.047	20
1.050	30
1.053	40
1.055	50

Solidifying point 10–15° C.:

Specific gravity $\frac{25}{25}$.	Per cent. phenol.
1.040	0
1.042	5
1.044	10
1.048	20
1.051	30
1.054	40
1.057	50

Solidifying point 15–23° C.:

Specific gravity $\frac{15}{15}$.	Per cent. phenol.
1.041	0
1.043	5
1.045	10
1.048	20
1.052	30
1.055	40
1.058	50
1.061	60

Solidifying points above 23° C.:

Solidifying point	23.5°	Phenol	70%
Solidifying point	29.5°	Phenol	80%
Solidifying point	32.75°	Phenol	85%
Solidifying point	35.5°	Phenol	90%
Solidifying point	37.75°	Phenol	95%
Solidifying point	40.5°	Phenol	100%

With solidifying points above 23° C. it was found that the variations in percentage of the cresols among themselves did not affect the solidifying point for any particular percentage of phenol.

Some mixtures would not be covered correctly by the above tables. For example, a mixture of 20 per cent. phenol and 80 per cent. *m–p* cresol melts below 0° and has a gravity of 1.040. This would indicate, as above, only 10 per cent. phenol. But such a mixture could *never* occur in a fraction obtained from natural materials, and therefore it is unnecessary, for practical analysis, to cover this ground. If it were necessary, the boiling points would be distinguishing, but to introduce these constants would make complications, and would not be of practical value for the purposes this paper is designed to cover.

In using these tables, the worker must exercise some judgment, as if a solidifying point were barely over 0° C. and the specific gravity were 1.040 at 25° C., the percentage of phenol would be more than 5 per cent. and less than 10 per cent., and about 7.5 per cent. should be taken. Conversely, near the upper end of a range of solidifying point the gravity would indicate

slightly less phenol than the figure given. If the figures are used intelligently and with real insight into their meaning, an estimation on the *fraction* within 2.5 per cent. of the true value should be readily obtained. Depending upon the total amount of tar acids in the original material, the results on the basis of the latter should be accurate between 0.2 per cent. and 1.5 per cent., and this is sufficiently close for all ordinary purposes.

The Disturbing Influence of Solar Radiation on the Wireless Transmission of Energy. NIKOLA TESLA. (*Elec. Rev. West. Elect.*, lxi, 34.)—The weakening of the impulses in wireless transmission is not due to ions liberated by sunlight, but to the evaporation of water on the hemisphere of the earth toward the sun, the conducting particles carrying off into the ground more or less of the electrical charges imparted. The Tesla system of transmitting energy through the earth is contrasted with the Herzian wave system.

Collection of Radium Emanation from Spring Waters. H. GREINACHER. (*Univ. Zurich Phys. Zeit.*, xiii, 435.)—In collecting water samples, loss of the emanation is avoided by the use of an exhausted glass globe with a glass stopcock instead of the ordinary container. The emanation is separated by boiling the water in the glass globe while it is directly connected to a partially-exhausted fontactoscope suitably modified. The use of the exhausted container insures the collection of water samples without loss of the emanation by inexperienced persons.

Meeting of the International Radium Standard Commission in Paris. O. HAHN, ST. MEYER, and E. v. SCHWEIDLER. (*Physik. Zeit.*, xiii, 524.)—A sample of pure anhydrous radium chloride prepared by Mme. Curie, and weighing 21.99 mg., was compared with three standard samples of radium chloride of the highest purity prepared by O. Hoenigschmid, of the Radium Research Institute of the Imperial Academy of Sciences of Vienna, weighing, respectively, 10.11, 31.17, and 40.43 mg. The activities of the several standards were found to agree within the limits of experimental error, 2 parts per 1000. Mme. Curie's standard was declared the official international standard, and is to be kept in the International Bureau of Weights and Measures in Sèvres, Paris. The Imperial Academy of Sciences of Vienna will be requested to deposit one of its standards, weighing 31.17 mg., in Vienna, as a supplementary standard. The commission formulated regulations for providing governments with secondary standards.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

COPPER WIRE TABLES.[1]

THIS circular discusses the results of work recently completed at the Bureau on the temperature coefficient and the conductivity of copper, as well as previous standard values, and gives a history of wire gauges, showing that the trend of practice is toward expressing diameter directly in decimal fractions of an inch.

There are fifteen tables, including complete reference tables for standard annealed copper, American Wire Gauge, both in English and in metric units; and similar abbreviated "working tables." There are also tables for bare concentric cables of standard annealed copper and for hard-drawn aluminum wire. The tables also include comparisons of wire gauges, and tables of temperature reductions, with complete explanations.

Four appendices give additional information—the first on the units used in the expression of resistivity; the second on the calculation of the "resistivity-temperature constant" and on the expression of the temperature coefficient; the third on the density of copper; and the fourth on the calculation of the resistance and mass per unit length of cables.

The status of the "Annealed Copper Standard" is given in paragraph 3 of the revised edition of this circular, as follows:

Ever since the American Institute of Electrical Engineers adopted the temperature coefficient, 0.0042 at 0°C., which vitiated the old wire table, the need for a new table was felt; and a recomputation of the old one had been under consideration. The need of more modern and representative data upon which to base the table had, however, been recognized, and the Bureau of Standards was requested to secure such data. The work was done in the first half of 1910, and reports of the investigations were presented to the Standards Committee of the Institute. At its meeting of October 19, 1910, that committee requested the Bureau of Standards to prepare copper wire tables, based on the

[1] Circular of Bureau of Standards No. 31, revised edition.

investigations, to replace the old wire table of the Institute. As a result of this action, a complete set of tables was prepared. On October 14, 1910, also, the United States Committee of the International Electrotechnical Commission voted that steps should be taken to interest the Commission in the subject of an international standardization of copper standards, and accordingly the question of standardizing the temperature coefficient was submitted to the other national committees by the United States national committee in letters of January 26, 1911. The question of a standard conductivity was considered by the national committees of several nations in September, 1911; and the result was an agreement among the representatives of Germany, France, and the United States to recommend a value proposed by Germany, differing only slightly from the value recommended by the Bureau and adopted by the Standards Committee of the American Institute of Electrical Engineers. The values for the temperature coefficient determined at the Bureau and corroborated at the German Reichsanstalt were accepted. For the standard resistivity thus defined, the name "Annealed Copper Standard" is proposed.

In order to facilitate the establishment of an international standard, and at the request of the Standards Committee of the American Institute of Electrical Engineers and the United States Committee of the International Electrotechnical Commission, the publication of the copper wire tables was withheld and they were recomputed on the new basis. This circular and its tables are the result. These tables give a concrete idea of the application of the proposed international copper standards. These standards have received widespread approval for international adoption since their suggestion about a year ago, and no other values have been proposed in the meantime for international consideration. Hence it seems very probable that in the event of international agreement these will be the numerical values adopted. If international agreement is not attained, the Bureau of Standards will make no further change in the numerical values. Hence, in either event, no further change of the basis of the Bureau is to be expected. In its certificates of tests of copper wire the Bureau will give per cent. conductivities both on the proposed international basis and on the old basis until January 1, 1914.

It is probable that the new standard will have been adopted

internationally before the date mentioned, and it is hoped that manufacturers, testing laboratories, and others concerned will have revised their standards in conformity with the new standard by that time. The various societies concerned have not as yet had an opportunity to act upon the matter, but the committees of some of them have considered and approved the proposed standards. As mentioned, the Standards Committee of the American Institute of Electrical Engineers has recommended them. The Copper Wire Committees of the American Society for Testing Materials, although opposed to changing the standard, have agreed to recommend their adoption when made international. The Wire and Cable Subcommittee of the Verband Deutscher Elekrotechniker has recommended them. The International Committee on Rating, of the International Electrotechnical Commission, has adopted a formal resolution recommending the proposed international standards to all countries. It is expected that the various national and international societies will act upon the recommendations during 1913.

Tungsten. ANON. (*Brass World*, viii, 9, 328 (from *Le Mois Scientifique.*)—Tungsten is used to make tungsten steel, filaments for incandescent electric lamps, and in the manufacture of projectiles. Tools made of tungsten steel do not soften when subjected to high temperatures and to the heaviest work. Tungsten alloys used for "high-speed" tools contain from 10 to 25 per cent. tungsten. Tungsten pure enough to be drawn to very fine wire is made by reducing its compounds in a vacuum furnace by the aid of hydrogen. These filaments have a greater conductivity than carbon filaments and give increased luminosity and at the same time consume less current. Tungsten 98½ per cent. pure is sold to-day for 50 cents per pound.

Starch Converted into Dextrin by X-Rays. H. A. COLWELL and S. RUSS. (*Phys. Soc. Proc.*, xxiv, 217.)—Solutions of starch in distilled water exposed to X-rays of moderate penetrating power in a dish covered with a thin sheet of mica were partly converted into dextrins, 5 per cent. of dextrin was formed in 8½ hours. This change might also have been produced by hydrolysis; but, according to Kernbaum, X-rays do not decompose distilled water, so that the X-rays, or the secondary rays to which they give rise, would appear to act directly on the starch molecule. Solutions of dextrins were not converted into glucose by X-rays under similar condition-

Color Photography by Prismatic Dispersion. J. and E. RHEINBERG. (*Phot. Journ.*, lii, 162.)—The apparatus and methods for this process are described as follows: (1) The real image is focused upon an opaque screen with narrow, transparent, parallel lines; (2) this real image is focused upon the photographic plate by a lens and prism which give for each point of each transparent line a microspectrum more or less incomplete, according to the local coloration of the object photographed; (3) the development of the photographic negative of these microspectra; (4) the production of a black-and-white transparency positive of the same; (5) the use of the positive as a screen in superposition to a series of complete microspectra produced by optical means in the camera, which is used as an instrument for viewing the picture. Each complete microspectrum is more or less cut off by the screen, and the result is a distribution of color in the field of view, reproducing the original colors. The history of the idea is given, and a detailed discussion of the optical requirements, such as plates, exposure, etc., adjustments, methods of viewing, and the possible further developments.

High Pressure Gas for Heating Furnaces. A. W. ONSLOW. (*Engineering*, xciii, No. 2424, 810.)—The best results are obtained by keeping the gas at constant pressure, and drawing in air under atmospheric conditions. If the pressure is steady, any heating furnace can be calibrated and desired conditions attained with certainty after the lapse of sufficient time to get the furnace thoroughly heated. Working at any definite pressure, a curve of furnace temperature plotted against time will always give a substantially straight line till the point of constant temperature corresponding to that pressure be reached. If the pressure be raised, the temperature will continue to rise until the new constant temperature point be reached. Thus it is possible to tabulate conditions for any heating furnace. A properly-designed gas furnace can be prepared from the cold state in a much shorter time than a coal furnace. In small work this may be a reduction of hours to minutes, and in large work of days or weeks to hours. The use of tiles of refractory material as baffles raises the temperature and gives better distribution. Pressures suitable for typical work are: For melting tin or solder a pressure of 65 inches is suitable, and that is also good for hardening in small furnaces. For bluing steel, from 65 to 80 inches is good. For the lead-pot for tempering steel the pressure should be 150 inches, while for melting metals at 2000° to 2600° F. it should be 200 inches. There is still needed a cheap yet efficient means of compressing the gas to the supply pressure of about 200 inches. Satisfactory heating burners are available, and the various phenomena on which economical and uniform working is dependent are now fairly understood.

FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, November 20, 1912.)

VICE-PRESIDENT COLEMAN SELLERS, JR., *in the Chair.*

Additions to membership since last report, 9.

The paper of the evening was presented by Alfred Noble, C.E., LL.D., of New York, entitled, "The Railway Tunnels of New York City."

A brief historical review of early tunnel projects served as an introduction, which was followed by a detailed description of the tunnels which are now in use in the city of New York.

The most approved systems of tunnelling, the various methods of carrying on the work without interference to traffic, and the obstacles met in tunnel construction, were given consideration.

The paper was fully illustrated by numerous lantern slides of engineering details and views of tunnels in various stages of construction.

At the close of the paper the Chairman extended the thanks of the Institute to the speaker, and the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, November 6, 1912.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 6, 1912.

DR. GEORGE A. HOADLEY *in the Chair.*

The following report was presented for first reading:

No. 2520.—De Vos' Rolling Sector Boat Davit. Advisory. Adopted.

The following was accepted for examination:

No. 2521.—The Hoover Suction Sweeper.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the section was held on Thursday evening, October 24, 1912, at 8 o'clock, in the Hall of the Institute.

Mr. George R. Henderson, Chairman.

The Chairman introduced Mr. James Donald, Consulting Naval Architect

to the Fore River Shipbuilding Company, Quincy, Mass., who read a paper on "Safety of Life at Sea."

The paper was discussed by Messrs. G. W. Dickie, Haig, Swan, and Rigg, Naval Constructors Snow and Leonard, and other naval architects present.

A vote of thanks was tendered Mr. Donald.

Adjourned.

FRANK B. STEM,
Secretary.

Physics and Chemistry Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, November 7, 1912, at 8 o'clock.

Dr. Harry F. Keller occupied the Chair.

The Chairman introduced Prof. Russell H. Chittenden, Director, Sheffield Scientific School, Yale University, who delivered a lecture on "The Chemistry of Nutrition."

Dr. Chittenden spoke chiefly on the influence of the character of proteins on growth and development in animal life. He contrasted the former methods of comparing food values by chemical analysis only, with the present-day methods of the physiologist, whose field of endeavor lay in the determination of the effect of enzyme and other action on the assimilation of foods.

After a brief discussion the thanks of the meeting were extended Dr. Chittenden.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mining and Metallurgical Section.—A meeting of the section was held on Thursday evening, November 14, 1912, at 8 o'clock, in the Hall of the Institute.

The meeting was called to order by the president of the section, Prof. Alexander E. Outerbridge, Jr.

After a few introductory remarks on the rapid development, in commercial use, of the electric furnace, the Chairman presented Mr. F. A. J. FitzGerald, A.B., B.S., of the FitzGerald & Bennie Laboratories, Niagara Falls, N. Y., who spoke on "Experimenting with the Electric Furnace."

Mr. FitzGerald described, with diagrams and photographs, the various forms of arc and radiation furnaces he had experimented with. He also spoke of electrodes, of induction regulators, pyrometers, and other important details in electric furnace work.

He exhibited samples of refractory materials used in lining furnaces, including Kieselguhr and carborundum bricks.

After a brief discussion, in which Dr. Hering and Mr. Clamer participated, the thanks of the meeting were extended to Mr. FitzGerald.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. CHAS. J. ALLEN, Fifth and Glenwood Avenue, Philadelphia.
DR. DAVID W. HORN, Box 12, Bryn Mawr, Pa.
MR. EDWIN WALKER KELLY, 5450 Pine Street, North Philadelphia.
MR. R. T. MARKEE, Sixty-fifth and Woodstock Streets, Germantown, Philadelphia.
MR. WALTER PALMER, Y.M.C.A., Chester, Pa.
MR. JULIAN STERN SIMSOHN, 909 North Franklin Street, Philadelphia.

NON-RESIDENT.

DR. HENRY SPENCER BLACKMORE, Mt. Vernon, N. Y.
MR. JOHN P. DONOHOE, 599 North Main Street, Greensburg, Pa.
MR. V. A. SUYDAM, Princeton, N. J.

LIFE.

COL. M. RICHARDS MUCKLÉ, 1722 Pine Street, Philadelphia.

Changes of Address.

MR. CARL G. BARTH, 6151 Overbrook Avenue, Overbrook, Pa.
MR. CALVIN F. CROWELL, 237 East Main Street, Moorestown, N. J.
MR. FRANK SHAW CLARK, Stone & Webster, 147 Milk Street, Boston, Mass.
MR. ARTHUR D. EDGERTON, Box 377, Marshfield, Ore.
MR. CHARLES H. FISH, P. O. Box 1593, Boston, Mass.
MR. A. SONNIN KREBS, 2340 Ash Street, Denver, Col.
MR. C. P. LANDRETH, 640 North Eighth Street, Philadelphia.
MR. CARLTON WILLIAMS, Blackwood, Camden County, N. J.
DR. GEORGE WOODWARD, Chestnut Hill Academy, Chestnut Hill, Penna.

Necrology.

Mr. Chas. W. Buchholz, 50 Church Street, New York City, N. Y.
Mr. Horace H. Furness, Wallingford, Delaware County, Pa.
Mr. Clement A. Griscom, P. O. Box 1569, Philadelphia, Pa.
Mr. J. N. Pew, Morris Building, Philadelphia.

NECROLOGY.

Charles Waldemar Buchholz, late consulting engineer to the Erie Railroad Company and member of The Institute since 1899, was born in Prussia sixty-nine years ago. He attended the technical school and gymnasium at Stettin until his seventeenth year, when, upon the death of his parents, following a natural inclination he made two voyages around the world. He came to America during the Civil War, in 1864, entered the Navy, and was honorably discharged at the close of the war, ranking as ensign for meritorious service. He then entered the employ of the Reading Railroad, and rose with this company from transit man to chief engineer of construction. In 1885 he was appointed chief engineer of the Erie Railroad. He held this office until 1892, when he accepted the position as president and chief engineer of the Quaker City Elevated Railroad of Philadelphia. He served in this capacity until the following year, when he returned to the Erie road. He continued as chief engineer to this road until 1903, when he was appointed consulting engineer—a position he held until his death.

He thus saw forty-seven years of active service as a railroad engineer, during seventeen of which he was connected with the Erie Railroad as its chief engineer.

Mr. Buchholz was a member of The Franklin Institute, the American Society of Civil Engineers, and of the Engineers and Transportation Club of New York, etc. He was a representative to the International Railway Congress at Berne, Switzerland, July, 1910.

Clement A. Griscom was born in Philadelphia in 1841. He was educated in the public schools of the city, and attended the Central High School for two years. At the age of sixteen he entered the shipping house of Peter Wright & Sons as a clerk and, by his unusual energy and ability, won quick promotion. When but twenty-two years old he became a partner in the firm. He gave particular attention to the various steamship enterprises it was interested in, and became a leading authority on both transatlantic and coastwise traffic.

In 1871 the International Mercantile Marine was organized and he was elected as its vice-president. He continued as such until 1888, when he succeeded James A. Wright as president. This concern passed through a remarkable development, and in 1902 it was reorganized and its name changed to the International Mercantile Marine Company. Mr. Griscom was chosen head of the new corporation, and continued in that position until 1904, when he resigned to become chairman of the Executive Board. He was, in addition, active in numerous other fields of finance. He was a director of the Pennsylvania Railroad Company, the United States Steel Corporation, United Gas Improvement Company, as well as of numerous banks and savings funds societies.

He was decorated by foreign royalties in recognition of his success in the organization of the transatlantic service.

Mr. Griscom was a member of The Franklin Institute since 1889.

LIBRARY NOTES.

Purchases.

ALLEN, C. F.—Field and Office Tables Specially Applicable to Railroads. 1912.
ALLEN, G. T.—Tables of Parabolic Curves. 1898.
BABBAGE, C.—Table of Logarithms of the Natural Numbers 1–108,000. 1889.
BAKER, C. H.—Brewing Calculations. 1897.
BAKER, T. T.—Simple Chemical Experiments. 2nd edition. n.d.
BARTLEY, B. C.—Marine Engineer's Record Book. 1897.
BATE, A. H.—Principles of Electrical Power. 1905.
BELLASIS, E. S.—Punjab Rivers and Works. 1912.
BUCKLEY, R. B.—Irrigation Pocket Book. 1911.
BYROM, T. H., and J. E. CHRISTOPHER.—Modern Coking Practice. 1910.
CANTELL, M. T.—Reinforced Concrete Construction. 1911.
CHARLETON, A. G.—Gold Mining and Milling in Western Australia. 1903.
COLLINS, H. F.—The Metallurgy of Lead. 2nd edition. 1910.
GERHARDI, C. H. W.—Electricity Meters. n. d.
GOLDINGHAM, A. H.—The Gas Engine in Principle and Practice. 1912.
GRAHAM, J.—Elementary Treatise on the Calculus. 1905.
HATFIELD, W. H.—Cast Iron in the Light of Recent Research. 1912.
HUEBNER, J.—Bleaching and Dyeing of Vegetable Fibrous Materials. 1912.
KEPPY, F.—Injectors. 1909.
MARLOW, T. G.—Drying Machinery and Practice. 1910.
MORGAN, A. P.—How to Build a 20-Foot Bi-plane Glider. 1909.
MORRISON, C. E., and O. L. BRODIE.—High Masonry Dam Design. 1910.
OLANDER, E.—Graphic Strains and Girder Construction. 1887.
POULSEN, A.—Cement in Seawater. 1909.
PRICE, W.—Turner's Handbook on Screw-cutting. 1912.
SCHNEIDER, N. H.—Electrical Circuits and Diagrams. 1904.
SCHNEIDER, N. H.—Study of Electricity for Beginners. 1906.
SHELFORD, F.—Pioneering. 1909.
STRANGE, W. L.—Indian Storage Reservoirs with Earthen Dams. 1904.
TAYLOR, F. H.—How to Use Electric Light. n. d.
TULLY, C. E.—Locomotive Slide Valve Setting. 1903.
VIGNIER, R. M. DE.—Model Steam Engine Design. 1911.
WAKEMAN, W. H.—Refrigeration, Ice-making and Refrigerating Machinery. 1907.
WRIGHT, F. B.—Inventions: How to Protect, Sell, and Buy Them. 1911.
XYDIS, C.—Handbook on Tacheometrical Surveying. 1909.

Gifts.

Isthmian Canal Commission, Canal Record, vol. v, 1911–12. Washington, D. C., 1911–12. (From the Commission.)
Canada Department of Mines, Mines Branch, Report on the Building and Ornamental Stones of Canada. Ottawa, 1912. (From the Department.)

London Meteorological Committee, 7th Annual Report. London, 1911. (From the Committee.)

Willans & Robinson, Inc., Catalogue of Steam Turbines and Diesel Oil Engines. Rugby, 1912. (From the company.)

U. S. Bureau of Foreign and Domestic Commerce, Department of Commerce and Labor, Imported Merchandise Entered for Consumption in the United States during the year ending June 30, 1912. Washington, 1912. (From the Division of Publication.)

Institution of Civil Engineers of Ireland, Transactions, vol. 38, List of Members, 1911–12. Ireland, 1912. (From the Institution.)

Baltimore & Ohio Railroad Company, 86th Annual Report. Baltimore, 1912. (From the company.)

Manchester Association of Engineers, Transactions, 1911–12. Manchester, 1912. (From the Association.)

Institution of Engineers and Shipbuilders of Scotland, Transactions, 1911–12. 1912. (From the Institution.)

Riefler, S.—"Tabellen der Luftgewichte, und der Gravitation." Berlin, 1912. (From the author.)

Ohio Inspector of Mines, Annual Report 1911. Columbus, 1911. (From the Inspector.)

Australia Commonwealth, Official Year Book, 1912. Melbourne, 1912. (From the Statistician.)

Missouri Bureau of Geology and Mines, The Iron Ores of Missouri. Jefferson City, 1912. (From the Bureau.)

Minnesota Historical Society, Collections 1912. St. Paul, 1912. (From the Society.)

North of England Institute of Mining and Mechanical Engineers, Report of Council, 1911–12. Newcastle-upon-Tyne, 1912. (From the Institute.)

Pennsylvania Museum and School of Industrial Art, Annual Report. Philadelphia, 1912. (From the School.)

Minnesota Railroad and Warehouse Commission, Annual Report, 1891–1903. Minneapolis, 1891–1903. (From the Commission.)

Vermont State Library, Finding List, Legislative Reference Department. N. p., n. d. (From the Library.)

Staffordshire Iron and Steel Institute, Proceedings 1911–12. Stourbridge, 1912. (From the Institute.)

PUBLICATIONS RECEIVED.

Les canalisations isolées. Conferences faites a l'Ecole Supérieure d'Électricité par J. Grosselin, Ingenieur civil des Mines. 96 pages, illustrations, plates, 8vo. Paris, Gauthier-Villars, 1912. Price, in paper, 3 francs 75c.

Celluloid: Its Manufacture, Applications, and Substitutes, by Masselon, Roberts and Cillard. Translated from the French by Herbert H. Hodgson, M.A., B.Sc., Ph.D. 356 pages, illustrations, plates, 8vo. Philadelphia, J. B. Lippincott Company, 1912. Price, in cloth, $7.50

Freezing-point, Boiling-point, and Conductivity Methods. Second edi-

tion, completely revised by Harry C. Jones, Professor of Physical Chemistry, in the Johns Hopkins University. 75 pages, illustrations, 12mo. Easton, Pa., Chemical Publishing Company, 1912. Price, in cloth, $1.

An Inductive Chemistry, by Robert H. Bradbury, A.M., Ph.D., head of the Department of Science, Southern High School, Philadelphia. 415 + 21 pages, illustrations, portraits, 12mo. New York, D. Appleton & Co., 1912.

Laboratory Studies in Chemistry, by Robert H. Bradbury, A.M., Ph.D., head of the Department of Science in the Southern High School, Philadelphia. 129 pages, illustrations, 12mo. New York, D. Appleton & Co., no date.

Canada Department of Mines, Mines Branch: Report on the Building and Ornamental Stones of Canada, by Wm. A. Parks, B.A., Ph.D. Vol. I, 376 pages, illustrations, plates, maps, 8vo. Ottawa, Government Printing Bureau, 1912.

U. S. Bureau of Mines: Bulletin 43, Comparative Fuel Values of Gasoline and Denatured Alcohol in Internal-Combustion Engines, by R. M. Strong and Lausen Stone. 243 pages, illustrations, 8vo. Miners' Circular 9, Accidents from Falls of Roof and Coal, by George S. Rice, 16 pages, 8vo. Technical Paper 24, Mine Fires: A Preliminary Study, by George S. Rice. 51 pages, 8vo. Washington, Government Printing Office, 1912.

Mesure de l'Équilibre des circuits téléphoniques par M. Béla Gáti ingenieur en chef des télégraphes de Hongrie. Extrait des Annales des Postes, Télégraphes et Téléphones (September, 1912). 8 pages, illustrations, 8vo. Paris, A. Dumas, no date.

Sugar at a Glance: Charts and data prepared by Truman G. Palmer concerning national economy and the high cost of living as affected by the increased yield of other crops when grown in rotation with sugar beets. Senate document No. 890, 62nd congress, 2nd session. 67 pages, illustrations, plates, 4to. Washington, 1912.

Canada Department of Mines: Summary report of the Mines Branch of the Department of Mines for the calendar year ending December 31, 1911. 208 pages, illustrations, plates, maps, 8vo. Ottawa, Printer to the King, 1912. Price, in paper, 10 cents.

BOOK NOTICES.

CHEMISTRY FOR BEGINNERS, by Edward Hart. Published by the Chemical Publishing Company, Easton, Penna. 214 pages, 12 x 16 cm. Price, $1.

The inexhaustible profusion in which elementary text-books of chemistry pour from the press is a remarkable fact. There is nothing about this book to differentiate it from the texts already in the field. Very much better books are available, and also very much poorer ones.

The text is not divided into chapters. There is to be a second volume, dealing with Organic Chemistry. The book is to be used without a laboratory manual, the experiments being distributed through the text. Many of the experiments require rather elaborate apparatus, and would be too difficult and dangerous for high schools. On the other hand, the descriptive and theoretical portions seem rather elementary for college students.

Slips are by no means absent. The candle of the Pasteur filter is not made of earthenware, and it is not necessary or desirable to heat it red hot in order to clean it (p. 26). The account of the manufacture of calcium nitrate from the atmosphere (p. 45) is very brief, but what there is of it is totally erroneous. In the historical account of the discovery of oxygen the name of Carl Wilhelm Scheele is not mentioned (p. 3). Experiment 141 (p. 102) would be dangerous in the hands of the beginner. The treatment of electrolysis and ionization is very inadequate (pp. 119–124). The diagrams of the Bessemer process cannot be understood from the description, while the open-hearth process, which at present furnishes about twice as much steel as the Bessemer, is dismissed in three lines (p. 179). The discussion of colloids is almost entirely confined to the rather ponderous (and, to the beginner, quite unnecessary) terminology of the subject, the epoch-making facts regarding molecular motion being ignored. The table of the periodic law (p. 204) is antiquated. The difficulty about placing the inert gases was solved years ago, and its solution constitutes one of the most striking triumphs of the periodic conception.

ROBERT H. BRADBURY.

A CONCISE HISTORY OF CHEMISTRY, by T. P. Hilditch. Published by D. Van Nostrand, New York, N. Y. 263 pages, 12 x 19 cm. Price, $1.25.

The appearance of short books of this type is to be accepted as an encouraging proof of the growth of interest in the historical side of chemical science. The present book is accurate and, in the main, well done. It bears the unmistakable marks of being intended for the use of students preparing for examinations in the subject. Too many topics are merely mentioned, and two few are adequately discussed. This gives some portions almost the appearance of a catalogue or a syllabus. In the reviewer's opinion, a subject should either be described in an intelligible way or be entirely omitted. However, it is impossible to follow this rule in a text intended for students preparing for examination. The book is well written and should be useful to the class for whom it is intended.

ROBERT H. BRADBURY.

PROBLEMS IN PHYSICAL CHEMISTRY, by E. B. R. Prideaux. Published by D. VanNostrand, New York, N. Y. 311 pages, 13 x 21 cm. Price, $2.

This is a unique and valuable book. The problems offered cover the whole field of physical chemistry. Some of the topics handled are "Units," "The Phase Rule," "Thermochemistry," "Gas Reactions," "Electromotive Force," "Molecular Kinetics," and "Radioactivity." Some of the questions are sufficiently difficult to test the powers of even the advanced student. The answers are given in all cases.

The knowledge gained from text-book and lecture is, at first, almost wholly verbal. It is not really a part of the student's mental equipment, and he may be able to talk fluently about a subject and yet be unable to make any use of the information he has acquired. The working-out of problems is one of the best methods of accelerating the transformation through which all knowledge must pass before it can actually be employed

for practical purposes. The student who has been carefully drilled upon a book like Morgan's "Physical Chemistry" and has, at the same time, worked his way through a selection of the problems in the present book will have more real knowledge of the subject than one who has listened to innumerable lectures.

ROBERT H. BRADBURY.

CHEMISTRY OF FOOD AND NUTRITION, by H. C. Sherman. Published by the Macmillan Co., New York, N. Y. 355 pages, 12 x 19 cm. Price, $1.50.

We have already noted the appearance of Professor Sherman's "Organic Analysis." The present volume takes up the subject of foods entirely from the view-points of Physiological Chemistry and Dietetics. "It is hoped that the more detailed description of individual foods and the chemical and legal control of the food industry may be treated in a companion volume later." This is a book which can be recommended with confidence to any one interested in the subject. The treatment is simple and intelligible, but entirely scientific. The author is completely familiar with the literature, and there is a freedom from fads and unsupported statements which, in a work dealing with Dietetics, is noticeable. There is a good index.

ROBERT H. BRADBURY.

ALLEN'S COMMERCIAL ORGANIC ANALYSIS, 4th edition. Published by P. Blakiston's Son & Co., Philadelphia.

Vol. IV, "Resins, Rubber, Gutta-percha, and Essential Oils," edited by W. A. Davis and S. S. Sadtler. 461 pages, 15 x 23 cm. Price, $5.

Vol. VI, "Organic Bases and Vegetable Alkaloids," edited by W. A. Davis and S. S. Sadtler. 721 pages, 15 x 23 cm. Price, $5.

This standard work is rapidly approaching completion. Only two volumes remain to be published, of which Vol. VII, which deals chiefly with vegetable and animal chemistry, is in press. Like those which preceded them, the present volumes have been rewritten and now contain an authoritative and complete account of the subject. The book is indispensable to the commercial analyst or, indeed, to any one whose analytical work is concerned with the organic side of the science. ROBERT H. BRADBURY.

HISTORY OF BRIDGE ENGINEERING, by Henry Grattan Tyrrell, C.E., Graduate of Toronto University, Bridge and Structural Engineer. 478 pages, illustrations, plates, 8vo. Chicago, Author, 1911. Price, $4.

Wherever a river and highway intersect some device is necessary for the crossing. It may be by a bridge above the stream, by a ferry on its surface, or by a tunnel underneath. Hence the ingenuity of man has been taxed from the earliest ages in devising structures for passing streams under all conditions. Their name is legion, and it is not only interesting but of great value to have available the graphic record of these works in condensed form.

Such a compilation has been made by Henry Grattan Tyrrell, C.E., of Evanston, Ill., published by himself, and issued from the press of G. B.

Williams Company, of Chicago. It contains some 400 pages, including an index of over 500 bridge builders and engineers and a subject list, based on locations, of more than 2000 structures, including nearly all types, excepting movable and military bridges.

Such a mosaic is the result of extended research and will serve as an admirable aid to the architect or engineer, who may thus obtain a comprehensive idea of the great range in style, material, and cost.

There are some 300 illustrations, taken from photographs, drawings, or diagrams in side elevation, showing in general the superstructure, but not the foundations, nor details, as these pertain to the science of construction, while this work is necessarily limited rather to the evolution of the art in its empirical stages than to the subsequent development of the scientific problem by Fairbairn, Brunel, Stevenson, Haupt, Whipple, and their successors, as embraced in the illustrious names in the index.

Although many long-span, wooden and stone bridges were built which were remarkable for their beauty and stability from the stand-point of the architect, it was not until after the introduction of railroads that the necessity for greater strength, economy, and rapidity of erection demanded a scientific analysis of the stresses in the several members and the corresponding distribution of the materials. This phase of the subject is not treated in this "History," which is confined to the completed structures. The demand for iron bridges on the Pennsylvania Railroad led to the rapid evolution of the science by the Chief Engineer of the company.

This book is timely and will fill a void in the general library of the engineering student.

LEWIS M. HAUPT.

CURRENT TOPICS

Vanadium in Chile, Argentina, and Peru. DAILY CONSULAR REPORT. (*Brass World*, viii, 9, 322.)—One of the Chile silver mines contains a valuable deposit known as Chileite, a brownish mineral containing 7.5 per cent. of vanadium, the use and importance of which is becoming greater every day. At Talcuna vanadium occurs in the form of a yellow earth between veins of copper ore, and near Cordova it is found in veins containing more than 5.5 per cent. of metal. Vanadium also occurs in rocks containing carbonaceous material. In Argentina lignite is found which yields 0.63 per cent. of ash containing over 21 per cent. of vanadium. A lead vanadate containing 14 per cent. of vanadium is found in the State of Cordova; it is black in color, with a yellow streak. An alloy of steel with only 0.25 per cent. of vanadium has a very high tensile strength and range of elasticity.

New Case Hardening Compound. P. W. BRENNAN. (*Brass World*, viii, 9, 310.)—The compound as patented by Mr. Brennan consists of

Potassium cyanide	2 ounces
Sodium bicarbonate	1 ounce
Potassium bicarbonate	1 ounce
Bone dust	½ ounce

The ingredients are powdered and mixed. The iron or steel to be case-hardened is heated and covered with the mixture, after which it is again heated to a bright red and plunged into water. The depth of the case hardening may be regulated by the number of times the iron or steel is heated with the mixture.

Atmospheric Ozone. H. N. HOLMES. (*Amer. Chem. Journ.*, xlvii, 497.)—The starch and potassium iodide reaction is given by ozone, hydrogen peroxide, and nitrogen peroxide. The effect of hydrogen peroxide is greatly accelerated in the presence of ferric sulphate, and nitrogen peroxide can be recognized by special tests. As a rule, the atmosphere contains only enough ozone to give the starch reaction; hence this reaction may be used for the ozone test in the atmosphere. The maximum amount of ozone is found when rapidly-moving areas of high barometer are so near the observer that quantities of air from great altitudes rapidly flow down to the earth. Most of the ozone is produced by the solar ultra-violet rays of the upper atmosphere; thunderstorms are of minor importance as generators of ozone.

Fire Tests with Glass. ANON. (*Engineering*, xciii, 2426, 874.)—The British Fire-Prevention Committee has recently published in No. 166 "Red Book" a report of two tests of "copperlite" glazing, supplied by Hayward Brothers and Eckstein, Limited, of London. The object of the first test was to record the effect of fire of 60 minutes' duration, the temperature to reach 1500° F. but not to exceed 1650° F., followed by the application of water for two minutes on the fireside, with the view of being classed as affording temporary protection (Class B). In the second test the object was to record the effect of a fire of 90 minutes' duration, the temperature to reach 1500° F. but not to exceed 1800° C. (*sic*, probably F. is meant), followed by the application of water for two minutes on the fireside, with the view of being classed as affording partial protection (Class A). In the first case neither fire nor water passed through the glazing, and the result was the same in the second case, so the classification desired was granted.

Corrosion of Steel in Water. G. J. BURROWS and C. E. FAWSITT. (*Roy. Soc., New South Wales, Journ.*, xlv, 67.)—It is believed that the first stage in the process of rusting is the solution, to a limited extent, of the iron in the water, with the formation of ferrous ions. The hydrogen thus produced, in the absence of free oxygen, polarizes the surface of the iron; then the function of the oxygen is the removal of the layer of polarizing hydrogen. If this be so, contact with a more electronegative metal, like platinum, should increase the speed of rusting. Experiments made to test this theory, using uniform steel strips fully immersed in unstirred distilled water, showed that such strips, when connected with platinum, rusted more rapidly than under ordinary circumstances. The steel used had the composition: 0.35 per cent. carbon, 0.61 manganese, 0.06 phosphorus, 0.01 silicon, and 0.01 sulphur. Experiments to test the influence of the composition of steel on the velocity of rusting in water containing 2.64 grammes sodium bicarbonate, 0.113 grammes magnesium sulphate, and 0.166 grammes sodium chloride per litre gave irregular results, from which few exact conclusions could be drawn. It was, however, noticeable that the initial rate of corrosion is very different from the rate developed after a few weeks, and that a steel containing from 0.9 to 1.0 per cent. of carbon rusts to a lesser extent than steels containing a smaller percentage of carbon. Magnetization has no noticeable effect on the corrosion of a steel of the composition given above. In discussing the work of Heyn and Bauer on corrosion, the authors state that the accelerative effect of salts on corrosion is explained by the greater conducting power of the solution, and that the decrease in the velocity of rusting with higher concentrations is probably due to the decreased solubility of oxygen in the solution.

Rotating Cathode. C. W. BENNETT. (*Journ. Phys. Chem.*, xvi, 287.)—The author has designed a revolving cathode which can be rotated at a speed up to 6,000 revolutions per minute, and which will carry 300 ampères, giving a current density of about 3,500 ampères per square foot when 4 inches of the cathode is receiving a deposit. This cathode is so arranged that the deposited metal can be removed for testing in suitable pieces without bending or heating. If the deposited cylinder is required as a whole, a thin shell of fusible metal is first cast around the cathode, and after the electrolysis the whole is immersed in boiling water. The full details of the construction are given.

Action of Ultra-violet Light on Chlorine. E. B. LUDLAM. (*Phil. Mag.*, xxiii, 757.)—As ultra-violet light ejects electrons chiefly from electropositive elements, though also from electronegative oxygen, the author tried the highly electronegative chlorine gas, which has a band in the ultra-violet, which band might prevent the ejection of electrons. According to Lenard, who conducted part of the research, a shorter wave-length is necessary to produce ionization in oxygen than is required to convert oxygen into ozone. The wave-lengths tried with chlorine and also with air ranged from 440 to 90 $\mu\mu$. There was very little ionization produced even in dry air by waves exceeding 200 $\mu\mu$; with wave-lengths below 180 $\mu\mu$ there was considerable ionization of pure dry air, which was enormously increased by a trace of water. Very small quantities of chlorine also increase the ionization of air, more chlorine stops it. Pure chlorine is not appreciably ionized, and does not form condensation nuclei when the illuminated gas is forced to impinge against an orifice from which a jet of steam issues. Considerable quantities of chlorine destroy any ions and condensation nuclei otherwise formed in the air. Thus chlorine does not appear to lose an electron easily, and traces of foreign matter appear necessary for the ionization of gases and for their chemical combination; yet actual liberation of electrons for a measurable period of time does not appear to be a necessary precursor of gaseous combinations.

Telephotography. O. WHEELER. (*Photogr. Journal*, lii, 62.)—A discussion of the usual formulæ employed in telephotography is given. It is suggested that advance in this branch of photographic work may be expected in the following directions: (1) High magnification, (2) special screens for long-distance work, (3) instantaneous telephotography, especially with reference to aërial reconnaisance, (4) panoramic telephotography, (5) color work. The use of compound tel-negatives is also discussed. During the discussion the relative merits of the hood and of a dead-black lining to the lens tube received considerable attention.

Contraction of Antimony-Lead and Aluminum-Zinc Alloys during and after Solidification. D. EWEN and T. TURNER. (*Rev. de Métallurgie*, viii, 728.)—During solidification antimony expands considerably, while lead does not change in volume. Their alloys show two maxima, one at the eutectic point, and the other at 50 per cent. lead; and two minima. The curve cannot be reconciled with the thermal equilibrium diagram nor with the Shore hardness diagram. In the aluminum-zinc series the expansion curve showed a maximum at the eutectic point, and in the remainder of the curve there appears to be a relation between the expansion and the solidification interval. Shore hardness tests and tensile strength tests indicate the existence of maxima in these values at 20 per cent. and 50 per cent. aluminum. The tensile strengths observed agree closely with those found by Bancroft. Cooling curves of alloys containing 2.4 to 60 per cent. of aluminum show a critical-point between 200° and 300° C., which reaches a maximum when the alloy corresponds to the composition $AlZn_2$. When quenched from 300° C. the alloy of this composition shows no eutectic point.

Capacity in Three-phase, Three-core Cables. A. B. CLARK. (*Elec. Rev.*, lxx, 532.)—The author proves from first principles how it is possible from two measurements of the capacity between certain elements of a three-core cable to deduce all other capacity values. All the requisite formulæ are proved, and the test results obtained show that they are in perfect accordance with experiment.

Autoclave Boiling Test for Concrete. H. J. FORCE. (*Eng. News*, lxvii, 1111.)—In the United States failures developed in concrete which had passed the ordinary test of boiling in water at atmospheric pressure, and these autoclave tests were made in consequence thereof. Briquettes of cement which had passed the ordinary test were covered with water in the autoclave and the steam pressure raised to 285 pounds per square inch in 45 minutes. After 1¼ hours further exposure the pressure was relieved. Some briquettes had swelled and they crumbled on removal; others, tested when cool, showed as much as 145 per cent. increase in tensile strength. The percentage water absorptions, the percentage expansions, and the fineness in a 100- and 200-mesh sieve were measured. The results are so conclusive that one of the railroads has adopted the autoclave test. The tests show that only the fine material in the cement enters into the reaction of setting, and to make the whole mass set the larger particles must be broken up. Age causes this to occur in large concrete structures with consequent disintegration. The claim that the failure to pass these tests is due to lime or free magnesia is rejected. Increasing the fineness of unsound cement improves its quality, and in every case the cement becomes sound if the material is sufficiently fine.

Cobalt-Carbon System. G. BOECKER. (*Métallurgie*, ix, 296.)—By heating pure cobalt with sugar charcoal in magnesia crucibles in an electric carbon-tube furnace alloys were prepared containing up to 3.9 per cent. carbon, which appears to be the saturation-point of cobalt for carbon at the temperature of 1700° C. Observation of the cooling-curves shows that the melting-point of cobalt, 1448° C., is lowered to a eutectic point at 1300° C. with 2.9 per cent. carbon. At 1300° C. the saturated solid solution contains 0.82 per cent. carbon, but as the temperature falls the solubility diminishes, and at 1000° C. only about 0.35 per cent. carbon is retained in solution. On slow cooling the carbon separates in the graphitic condition. These conclusions are confirmed by micrographic analysis.

Crystallization and Structure of Slowly-cooled Steel. N. T. BELAIEW. (*Rev. de Métallurgie*, ix, 321.)—The crystallization and structure of iron-carbon alloys containing less than 2 per cent. of carbon were studied. All the alloys were kept molten for two hours, and then allowed to cool slowly, so that 60 hours elapsed while the temperature fell from 1500° C. to 300° C. During this slow solidification "primary crystallization" occurs with the production of interlocking dendrites built up of octahedral crystals. When conditions are favorable this dendritic structure is visible to the naked eye, and it can always be developed by the prolonged etching of polished specimens. The decided indications are that the resulting solid solution is not homogeneous. During the solid solution range of temperature neighboring octahedra of similar orientation aggregate to form polygonal grains. At the eutectoid temperature the so-called secondary crystallization takes place, depositing ferrite or cementite, which forms envelopes for the pearlite grains and gives rise to the cellular structure. The secondary crystallization is markedly influenced by the foregoing phenomena. If the secondary crystallization occurs very rapidly, the structural constituents, ferrite and cementite, arrange themselves parallel to the four surfaces of the octahedron and form Widmanstätten figures inside the grains. This combination of the net-work and Widmanstätten figures has been termed the Widmanstätten structure. The examination of the structure of isolated crystals, which have developed in cavities, shows that the axes of dendrites coincide with the lines of deposition of the ferrite and cementite. Such a structure is called the "structure of large crystals."

Electrolytic Preparation of Persulphate. A. BLUMER. (*Zeitsch. Electrochem.*, xvii, 965.)—Experiments were made with M. Le Blanc's anode, consisting of four rings of platinum wire, held by a skeleton-cylinder of glass rods, and two electrode tubes of mercury. The details scarcely admit of abstraction.

The Ammonia Flame. A. C. EGERTON. (*Nature*, lxxxix, 270.)—Ammonia burning in oxygen gives a yellow flame, resembling the nitrogen glow of Strutt, and with a similar spectrum. The ammonia seems first to be split up into nitrogen and hydrogen, and the inner, bright yellow cone of the flame is apparently due to the combination of nitrogen atoms to molecules, as in the nitrogen glow; while in the outer, hardly luminous cone, the hydrogen is burned to water, and some nitric oxide is formed. Flames due to the combination of substances generally have a pointed cone, whilst in the ammonia flame the inner cone assumes a rounded apex.

Solubility of Wrought Tungsten and Molybdenum. W. E. RUDER. (*Amer. Chem. Soc. Journ.*, xxxiv, 387.)—Tests were made on discs of sheet tungsten, 18 mm. in diameter and 2 mm. thick, with hydrochloric, sulphuric, nitric, and hydrofluoric acids, aqua regia, alkaline carbonates, and potassium hydroxide. At room temperature the first three acids, whether concentrated or dilute, have no effect, except dilute nitric acid, which forms a yellow, surface oxide. Fused potassium hydroxide attacks the metal slowly. Hot or cold hydrofluoric acid does not attack tungsten, but does attack tantalum; but mixed hydrofluoric and nitric acid dissolves tungsten, forming tungstic oxide. Molybdenum is much more easily dissolved than tungsten. It resists concentrated hydrochloric and sulphuric acid below 1250° C. fairly well, and is not attacked by hydrofluoric acid.

Central-station Power for Municipal Pumping. ANON. (*Elect. Rev. and West. Electn.*, lx, 1033.)—In this article the principal advantages of central-station power for municipal pumping are pointed out, with comments on important pump and motor characteristics, which should be considered when changing over to electric drive; and gives comprehensive data on a large number of plants now working satisfactorily. Two types of pump should be considered for driving by electric motors—the various forms of the plunger type, and the centrifugal type. The plunger type is usually triplex, and either single- or double-acting, and is a little more efficient than the other; but it is essentially a low-speed machine, limited to about 30 revolutions per minute. Therefore it requires speed reduction, and thus increases cost and adds complexity. On the other hand, the centrifugal pump can be directly connected to motors operating at their normally high speeds, up to about 1,500 revolutions per minute, and thus is low in first cost, compact, and easily operated. Furthermore, centrifugal pumps are suited to direct-pressure service. Both types give reliable and satisfactory service when used under those conditions to which they are essentially adaptable.

Spectrum of the Brooks Comet (1911c). A. DE LA BAUME PLUVINEL and F. BALDET. (*Comptes Rend.*, cliv, 1286.)—During the time the comet was visible 22 good spectrograms were obtained with a specially-designed prismatic camera. Important changes in the spectrum were observed as the distance from the sun varied; but these changes were confined to the nucleus only. There was evidence that the sodium lines, and perhaps the iron lines, became stronger in the spectrum as the comet approached the sun. Further, as the sodium lines became stronger the Swan carbon spectrum diminished in intensity. The negative pole spectrum of nitrogen was apparently absent from the spectrum of this comet.

Sealing Metals. P. E. SHAW. (*Phys. Soc. Proc.*, xxiv, 95.)—Threlfall used Margot's solder (92 per cent. tin, 8 per cent. zinc) to fasten glass, aluminum or quartz surfaces to any other. Other solders are found efficient, viz., tin, zinc, various alloys of tin and zinc, tinman's solder, and aluminum. Besides these, there are many materials with melting points between 180° and 660° C. For these and similar materials which act like sealing-wax, the name "sealing-metals" is suggested. They have the advantage over wax in high melting-point and the non-emission of vapor at high temperatures.

Developments in Steam Turbine Engineering. E. D. DREYFUS. (*West. Soc. Engin. Journ.*, xvii, 413.)—This article is a *résumé* of progress in turbine design, showing the special work for which different designs are most applicable; and the variations in construction dependent on working conditions and the capacities required. In a few years the range of capacities in use has been extended from 1 to 20,000 kilowatts per machine; and now turbines of 30,000 horse-power are being built. The single-disc wheel construction is used up to 300 kilowatts; such small turbines are largely used for auxiliary service, excitation, pumps, etc. Reference is made to the variety of systems of governing low-pressure turbines, and the design of a convertible type of low-pressure turbine is illustrated. It is a single-flow reaction element with a provision for the introduction of a high-pressure impulse wheel when conditions require it. The pressure relations between reciprocating engines and turbines in a combined system are considered, and the curves of combined water-rates of a given engine and low-pressure turbine with varying load are given. Many designs are illustrated, among them an automatic "bleeder" turbine for combined electrical and steam-heating loads, and the relation of steam distribution and power load with the variable bleeding demand is diagrammatically illustrated. Various methods of applying turbines are referred to and illustrated, such as several arrangements of the Leblanc condenser applications, and centrifugal pump and blower designs.

Railway Equipments. K. SIMMON. (*Elect. Rwy. Journ.*, xxxix, 1111.)—In this article some recent experiences are recorded. It is pointed out that motors are often geared too high, and that in some cases it is economical to lower the gear ratio. Other improvements in motors are referred to, and it is shown that mere reduction of weight may be carried too far and results in frequent repairs. Many improvements lately introduced are mentioned, such as multiple-unit control, field control, low platform cars, high voltage direct current, and the single-phase systems. It is expected that there will be in future a considerable extension of the multiple-unit system of control.

Examination of Eggs by X-Rays. ANON. (*Rev. Sci.*, 1, 25, 791.)—The Roëntgen X-rays are now used for determining the condition of eggs (candling). At the place where the eggs are received a dark room is arranged with a Crookes tube set in a lantern, hermetically sealed except one aperture just large enough to enclose a hen's egg. The egg is placed in this aperture and exposed to the X-rays. Fresh eggs are perfectly translucent; if a little old, a small spot is visible on the fluorescent screen; if the spot is large or if it moves about, the egg is bad, and is rejected. The larger egg merchants of London will only accept "examined eggs." By this method spots may be clearly seen which are so small as to be invisible to the naked eye.

A New White Non-corrosive Alloy. ANON. (*Mech. Eng.*, xxix, 411.)—This alloy consists of iron 30 to 70 per cent., nickel 25 to 50 per cent., and copper 5 to 20 per cent. It can be cast, rolled, and drawn. It is important to keep the carbon within 0.2 per cent. to prevent the formation of hard nodules. An alloy containing 65 per cent. iron, 25 per cent. nickel, 10 per cent. copper, and 0.2 per cent. carbon has an elastic limit of 51,750 pounds per square inch and an ultimate stress of 96,100 pounds per square inch, with an elongation of 42 per cent. in 2 inches, and a reduction of area of 53.7 per cent. In making the alloy a small amount of manganese or magnesium is used as a deoxidizer because of the low content of carbon.

Electricity Direct from Coal. W. RAMSAY. (*Elec. Rev. West Electr.*, lx, 692.)—By producing gas direct from the coal bed, it is expected to produce electricity by means of gas engines at the pits' mouth with a saving of 30 per cent. of the available coal energy, as against 15 per cent. now available in fuel engines. Concentric tubes through a bore-hole to the coal substratum would furnish a means of electrically igniting the coal, and, if steam be blown in, would give a mixture of hydrogen and carbon monoxide, or water gas, which would be used as fuel for the gas engines.

Electrical Properties of Crystals. Stratification and Capacity of Carborundum. G. W. PIERCE and RHYS D. EVANS. (*Proc. Am. Acad. Arts. Sci.*, xlvii, 793.)—The electrostatic capacity of carborundum crystals was measured by a method of charge and discharge. The capacity of one specimen was about 0.006 microfarad, and of another about 0.022. The existence of capacity in the crystal was found to be due to numerous alternate conducting and insulating strata within the crystal. These strata are visible with vertical illumination and moderate magnification. Photomicrographs are given in the article. The action of carborundum as a detector for electrical waves and as a rectifier for electrical currents, is independent of its action as a capacity. It will detect or rectify only when contact is made to one or more of the conducting strata. It may detect electrical waves with an adjustment that shows no capacity, but with every adjustment at which capacity was found there were also rectification and detection of electric waves.

Origin of Canadian Apatites. W. H. MCNAIRN. (*Trans. Can. Institt.*, viii, 495.)—Most of the apatite occurs in beds, intercalated with the Grenville limestone, in gneiss, accompanied by graphite, magnetite, anhydrite, etc. There are no true gangues. Its formation is reported to be: (1) Decomposing organic matter can absorb phosphoric acid from very dilute solutions. (2) Each phosphate stratum (except the true apatite) can be regarded as of direct or indirect organic origin. (3) Phosphates of known organic origin can unite with fluorine from water and form the true apatite molecule. (4) This process took place in early geologic times. (5) The enclosing rocks contain phosphoric anhydride, only in the form of apatite or as molecular admixtures. (6) The Canadian apatites occur in deposits which are in great part stratified. (7) Accompanying the apatite are anhydrite (undoubtedly sedimentary), calc-spar, gypsum, and magnetite, which have been formed apparently by organic means. (8) The coloring matter in the apatite and the accompanying limestone is organic. (9) The apatite crystals, and in a less degree the accompanying minerals, have been eroded later. The calc-spar contains detached parts of apatite. From the above the formation of Canadian apatites is traced as follows: (1) They are the final product of an accumulation of organic matter containing phosphoric anhydride, their content of which has been greatly augmented by the evaporation of sea-water. (2) The phosphates so formed remove fluorine from the water and thus form the true apatite. Fluorine was in many cases replaced by varying amounts of chlorine, forming the different varieties of apatite. Later changes finally gave the calcium fluophosphate its crystalline form. (3) The peculiar eroded appearance of apatite is attributed to the effect of calcium carbonate in a more or less fluid condition.

Weight of a Litre of Atmospheric Air at Geneva. PH. A. GUYE, J. KOVACS, and E. WOURTZEL. (*Rev. Sci.*, l, 25, 794.)—The weight of a litre of dry air, freed from carbon dioxide, was 1.2928 grammes, as weighed by Lord Rayleigh in London, 1.2927 Gm. weighed by Leduc in Paris, and 1.2930 Gm. weighed by Guye, Kovacs and Wourtzel, at Geneva, showing differences of $^{2}/_{10}$ and $^{3}/_{10}$ of a milligramme. This indicates that the mean density of the air varies in different localities, although within very small limits. This was verified by weighing three samples of air taken simultaneously at Geneva, at a height of 400 metres, at Mt. Salève, at 1280 m., and at Rochers de Naye, at a height of 2045 m. Thus the density of the air varies by some tenths of a milligramme at places not far apart.

The Action of Gelatine and Other Colloids in Retarding the Reduction of Silver Chloride. W. REINDERS and C. J. VAN NIEUWENBURG. (*Z. Chem. Ind. Kolloide*, x, 36.)—The speed of reduction of silver chloride by iron citrate, in the presence of gelatine and other colloids, depends on the nature of the colloid present and its concentration. In every case the speed was less than when no colloid was present, and decreased as the concentration of the colloid increased. Albumin decreased the speed of reduction most, then "Acid Violet 6B," gelatine, agar-agar, gum arabic, "Ponceau 3R," in the order named. The reduction is effected in two steps: solution of the solid salt, then reduction and crystallization of the reduced silver. It was shown experimentally that the presence of gelatine had no effect on the speed of solution of the silver chloride, but greatly affected the speed of crystallization from the solution.

Globoid Worm-Gearing. PEKRUN. (*Zeitschr. Vereines Deutsch. Ing.*, lvi, 442.)—Globoid worm-gearing, often called Hindley worm-gearing, is characterized by the fact that the pitch surface of the worm is not cylindrical, but a surface of revolution generated by the pitch-circle of the worm-wheel about the worm-axis. This form has practical advantages and was known to Leonardo da Vinci. The efficiency of the globoid worm is in general greater than that of the straight worm, which after running some time tends to wear to the globoid form. With worm-gearing of either of the above shapes the frictional losses are great. Hence the so-called Pekrun-gear was introduced, wherein the teeth of the worm-wheel are rollers, with axes in the plane of the worm-wheel and perpendicular to its axis. With this gearing, tests by several independent experimenters yield efficiencies of 93 to 95 per cent. Thus the position of agent and object can be interchanged at will, so that either large reduction or multiplication of speed can be obtained. In the latter sense the Pekrun gear has been applied to milk centrifugals.

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